# The Plant world

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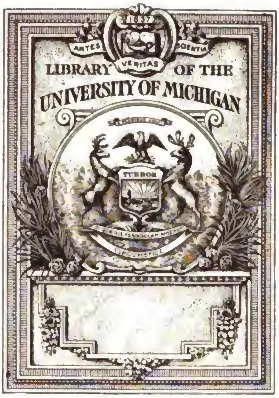
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# THE PLANT WORLD

## A Monthly Journal of General Botany

Established 1897

*Edited by*
FORREST SHREVE

*Published by*
THE PLANT WORLD ASSOCIATION

## Volume 21

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# THE NATIVE BANANAS OF THE HAWAIIAN ISLANDS

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The banana occupied an important place in the dietary of the ancient Hawaiian, as it did with all the Polynesian peoples. The early European explorers all comment upon the numerous groves and plantations of bananas in the vicinity of the native settlements. The ease with which the plant was propagated, the little culture it required, the profusion and perennial quality of its growth, and its abundance of nutritious and palatable food, all combined to give it high rank in the primitive Hawaiian agriculture.

With the decadence of the native population, and the introduction of large numbers of alien peoples with food-habits entirely different from those of the Hawaiian, the native banana diminished in importance as a staple of diet. Foreign varieties were introduced from time to time, and in a number of instances, notably that of the Chinese banana, became more numerous, both in cultivation and in the markets, than the original native varieties.

It is the purpose of the present paper to discuss somewhat in detail the native varieties as distinguished from the now-preponderant alien bananas. Brief consideration may be given, at the outset, to some of the more prominent of these introduced kinds, in order to make clear the differences between the two groups. A person visiting the Hawaiian Islands today would find the standard commercial variety to be the Chinese banana, *Musa cavendishii*. It was introduced from Tahiti about 1855, and rapidly found favor in its new home. In the vicinity of Honolulu, at various points on the island of Oahu, and to a lesser degree on the other islands, are extensive plantations of this species. The local consumption is large, and there is considerable

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export to California. The factors that have given this species commercial supremacy are numerous. Owing to its dwarf size and deep rootage, it does not suffer from wind and storm as do the tall-growing kinds. It stands close planting, and thus gives a much larger yield per acre than do the varieties which require more room. It bears sooner than do many of the native bananas. The bunches are large and well-filled; the fruit, although excelled by many of the other varieties, is of good flavor and texture. It is likely to steadily gain in importance.

A second introduced species, of totally different character, is the *Musa fehi* of Tahiti. This banana is common in the forests of Tahiti, and was probably brought to Hawaii from Bora Bora, an island of the Tahitian group. There it is called Fe'i. The Hawaiian name, Pola-pola, is corrupted from Bora Bora, and has in turn been corrupted in English to Bolo-bolo. This banana does not come from Bolo-bolo. The natives also call it He'e. The peculiarity of this species is that the stem of the bunch stands *erect*, holding the bunch straight up, instead of hanging pendant, as do most bananas. The fruit is oblong, nearly straight, and of fair quality when cooked. The plant is a tall, vigorous grower; the base of the stem is black, the upper part green. The petiole is short and stout as compared with the length of the blade; the latter is dark-striped. This variety occasionally grows uncultivated in spots in the Hawaiian forests where it has been planted, and in such places is easily mistaken for a native variety. It is reported as occasionally producing seeds in these islands; in Tahiti it often produces seeds at elevations above 3000 feet.

Another exotic variety, that was introduced from Tahiti about 1855, is the so-called "Brazilian" banana, known to the natives as Nuho-lani. This is the "Dessert Banana" of Java, and is a choice and highly esteemed variety wherever it occurs. The plant is a vigorous grower, 25 to 35 feet high, firmly rooted, and withstanding winds. It suckers freely, and is often used as a windbreak for more delicate varieties. The apex or floral end of the fruit is prolonged into a distinct beak or rostrum. The skin of the fruit is smooth and delicate, clear bright yellow, and easily separated from the flesh. The flavor is excellent, with a piquant sub-acid taste that relieves the otherwise almost cloying sweetness. The fruits are so easily loosened from the bunch that this variety is not adapted for shipping. Often in gathering a thoroughly ripe bunch, a large proportion of the fruits shatter from it as it is taken from the plant. Other exotic varieties are the Bluefields, the Ice Cream, the Apple, the Lady Finger, and the Abaca, (*Musa textilis*, Manila hemp).[1]

The ancient Hawaiians recognized by distinctive names over twenty varieties of banana. The number was probably much larger than this, as many of the local and lesser-known varieties have long been extinct, exactly as in the case of the taro and the sweet potato. These varieties can be arranged in three groups, each group segregated about a dominant type, Maoli, Iho-lena, and Po-po-ulu. The following list contains detailed information, so far as is available, concerning the characteristics of each variety. In the Hawaiian language the generic name for banana is *maia*, to which is added the specific or varietal name, as for example, Maia Iho-lena, Maia Hua Moa, Maia Kana-lua. In the list only the varietal names are given. All of the native bananas are varieties of *Musa sapientum.*

*Aa-o.* This name is applied by the natives to a very rare tall-growing variety, restricted to glens and recesses in the mountains, and not found in cultivation; other characters unknown.

*Ele-ele.* A variety belonging to the Maoli group. The trunk, petioles and midribs are all very dark, almost black; this character gives the name, which means dark or black. The young fruit also is so dark that at a distance it looks black. The dark leaf-sheaths, petioles, and mid-ribs furnished materially formerly used by the natives in making hats.

*Ha-a.* A variety belonging to the Iho-lena group. The plant is of low stature, 6 to 8 feet, even smaller than the Iho-lena. The leaf-blade is light, clear green. The stem is light green with numerous longitudinal blackish streaks. This streaking is constant and forms a varietal character. Under favorable conditions it fruits much sooner than other varieties. The bunch is short, but large. The fruits are pointed at the apex. This is one of the choicest varieties for cooking. It closely resembles the Iho-lena, and is sometimes called Iho-lena Ha-a.

*Hai.* A variety belonging to the Maoli group. This variety forms the largest plant of any of the native bananas, and produces the largest bunch of fruit. Plants twenty-five feet high are not uncommon. The individual fruits are also very large. The Hai is not as hardy as some of the other varieties, and if neglected it often fails to produce vigorous suckers, and eventually dies out. This variety is known especially in Kona, Hawaii.

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[1] See Higgins, J. E., The banana in Hawaii, Haw. Agr. Expt. Sta. Bul. 1906.

*Hapai.* A very curious native variety; probably the same or closely related to the "Lubang" or "Eel plantain" of Java. The bunch is very small and is ripened *within* the stem of the parent plant; that is, the bud does not emerge from within the stem. This variety is also called Huaiwaena, which refers to this curious development.

*Hinu Pu-a'a.* A variety belonging to the Maoli group. The stem is black, and in a number of characters this variety closely resembles the Ele-ele. It is found in the upper valleys and ravines, and on steep slopes.

*Hua-moa.* Literally "hen's egg," referring to the size and shape of the fruit. This variety belongs to the Po-po-ulu group. The plant is of medium height, and rather stocky; the leaves are very numerous, and droop from long, slender petioles. These features give the crown a characteristic appearance. The bunch-stem is very slender. The fruits are markedly egg-shaped, and few in number, often there are only two or three fruits on the bunch. The fruit has a tendency to crack open before thoroughly ripening, hence it must be gathered early. The flavor is very fine, and the flesh is rich and creamy. It is a highly prized variety, but is uncommon.

*Hua nui.* This variety is remarkable in that it usually produces two, three, or four bunches of fruit from the same stem or trunk. These bunches are produced consecutively, over a long period of time, twelve to eighteen months. The bunches are small, and the fruit of medium quality. The variety is also called Hua alua ("two fruits"), and Mahoe ("twins"), referring to the unusual number of bunches.

*Iho-lena.* One of the best known of the native bananas. The plant is of medium stature, averaging about 10 feet to the tops of the leaves. Trees 12 and 14 feet high are not uncommon in favorable localities. The petioles are rather stout, and are light green in color with reddish markings along the margins. The undersurfaces of the new leaves are slightly bronze or purplish. The fruit bunch is rather small; the fruits are loosely arranged, and stand out at right angles from the axis. This gives the bunch a characteristic appearance. The fruit is conspicuously angular in cross-section. The skin of the immature fruits is a delicate light green, turning lemon yellow before ripening. The flesh is pale pink. When thoroughly ripe, and beginning to turn black, it is regarded by the Hawaiians as one of the best varieties for eating raw; it is also excellent for cooking. The Iho-lena is widely distributed over the islands, and is known by a number of names: Loha, Iho-u, Hili-hila. The Iholena group of bananas includes the Lele, the Ha-a, and the Pua-pua-nui.

*Ka-io.* This variety belongs to the Po-po-ulu group; it is very similar to the Po-po-ulu, but is somewhat taller, and the fruit is inferior in flavor. This variety occurs wild in the mountains, in ravines and hanging valleys, and near the summit ridges.

*Kana-lua.* A variety belonging to the Maoli group; it has the shortest stem of the group, averaging about 14 feet. It is also distinguished by its dark green foliage, which resembles in shade the foliage of *Musa cavendishii.* Although the bunch is rather small, the fruit is of good quality and flavor, and resembles the Poni. Kana-lua is best known on Maui and Hawaii.

*Ko-a'e.* A variety easily recognized by the white striping on the leaves and fruit; probably *Musa sapientum* var. *vitata.* The petioles are striped with white, and there are blotches of white on the blade; the fruit is striped longitudinally with white. The varietal name fancifully compares these markings with those of the tropic bird, *ko-a'e.* The plant is 14 to 18 feet high. The fruit is of fair quality when cooked. This variety is most abundant in moist parts of the islands, as the Hilo region of Hawaii; windward Maui, and eastern Molokai. It is also called Ae-ae and A'e.

*Lele.* A very tall variety belonging to the Iho-lena group. The plant is 18 to 24 feet tall, with a robust stem and a large crown of heavy foliage. The stem is blacker than that of the Ha'a. The petioles, and the leaf-sheaths at the upper part of the stem, are of a very light green; this is a conspicuous character. The new leaf-blades show bronze tints on their under-surfaces, but not as conspicuously as Iho-lena. The bunch is hung on a very long scape. The fruits very closely resemble those of the Iho-lena, and are arranged on the bunch in the same way. The flesh is pink, and excellent in quality. The Lele occurs on all the islands, from Nii-hau to Hawaii,

*Loha.* A peculiar variety, possessing the characteristics of both the Maoli and the Iho-lena types. The feature which distinguishes it from all the other native bananas is that in the Loha bunch the individual fruits hang *downwards* toward the ground, instead of being semi-erect. The plant is quite tall, 14 to 18 feet,—the leaves resemble the Lele. The fruit, if not bruised, is very good, but a slight bruising, even while green, destroys the texture and begins decay. This variety is known only from the island of Molokai.

*Ma-nae-ula.* A variety belonging to the Maoli group. The upper part of the stem or trunk has a conspicuously reddish or purple color, which extends out more or less into the petioles and midribs of the leaves. The most striking and distinctive peculiarity, however, is the very dark red color of the immature fruits or ovaries of the flowers when they first appear. As the fruits increase in size this color gradually disappears, and they assume the dark green shade characteristic of the Maoli group. This variey occurs on Kauai, Oahu, and Molokai; and probably on the other islands. It is sometimes called Ma-lai-ula.

*Maoli.* This is the commonest variety of the group of cooking bananas to which it gives its name. The stem is very tall, 18 to 25 feet; when young it is light green with faint tints of pink or purple; when mature it is dark green. The fruit bunch is long and large. The fruits are quite long, and round in cross-section. They are conspicuously blunt or rounded at the apex, and are turned more or less upwards. When immature the fruit is dark green; when ripe it becomes orange yellow; the flavor is excellent. Together with several closely-related forms, it furnishes most of the cooking bananas sold in the Honolulu markets. The other members of the Maoli group are: Puhi, Ma-nae-ula, Kana-lua, Hai, Ko-a'e, Poni, Loha, and Hinu-pua'a. The Maoli is also sometimes called Ka-hiki,—both of these names are suggestive of the South Sea ancestry of the Hawaiian people and their economic plants.

*Moa.* A variety belonging to the Po-po-ulu group. The stem is very tall, 16 to 22 feet. The bunches are small, having only a few rows of fruit, and not uncommonly only two or three fruits. The fruit is large, egg-shaped (whence the name *moa*), and with a rough skin. According to Higgins this variety is undoubtedly the same as Hua-moa; he says "It is probable that the two varieties are not distinct, the differences which have given rise to the two names being due to the immediate effect of soil and cultivation."

*Nou.* An obscure variety belonging to the Po-po-ulu group. It is very short-stemmed, only 3 to 5 feet high, and is said to do well in windy places where other kinds will not thrive.

*Poni.* A variety belonging to the Maoli group. It is similar to the Maoli, but with purple petioles and midribs, and a reddish stem. The leaf-blades are sometimes blotched with red or purple. The bunch and the fruit are both shorter than in the Maoli. Also called O'a.

*Po-po-ulu.* A well-known variety of cooking banana, common in the Honolulu markets. The plant is of medium height. The stem is green with a slight tendency to pinkish tints on the petioles. The scape is rather slender; the bunch itself is of medium size. There are 8 to 10 fruits per hand. The fruits are short, thick, rounded, and blunt at the ends. This banana is of good quality when cooked; the flesh is firm and sweet. Other members of the Po-po-ulu group are: Ka-io, Hua moa, Moa, Nou, and Lahi.

*Pua-pua-nui.* A variety of the Iho-lena group. This one has the largest stem or trunk of the group; it often reaches a height of nearly 30 feet. In other features the plant is similar to the Ha'a; the bunch, however, is smaller and shorter than the Ha'a. The fruits diverge at the ends. This variety is also called Pu'u-hala, Ka-pua, and Maoli-ili lahi-lahi. It is frequent on the windward sides of Hawaii, Maui, and Oahu.

*Puhi.* A variety of the Maoli group. The distinguishing feature of this variety is the great length of the fruit as compared with the small diameter. The fruit is also somewhat curved or twisted, and thus the varietal name fancifully compares it to the eel "*puhi*."

All of the native bananas are seedless, and could have reached the islands only through human agency. The vegetative shoots or "suckers" are quickly killed by sea-water, and could not have been carried by the ocean currents in the manner in which many impervious-tegumented seeds are carried. The banana was undoubtedly introduced by the primitive Hawaiians, together with numerous other plants of economic value, from their home in the South Pacific.[2] In fact, there is abundant evidence to show that the Polynesians, from their first migrations out of the mysterious south-Asian "Hawa-iki" home-land, took with them such plants as the bread-fruit, sweet potato, and banana, and such animals as the dog, hog, and fowl. These and other more distinctively Polynesian plants and animals are scattered all along the great migration routes of this adventuresome people.

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[2] See MacCaughey, Vaughan, The food plants of the ancient Hawaiians. The Scientific Monthly, **4**: 75–80, 1917.

Upon settling in the Hawaiian Islands, the villages were established along the coasts. The primitive agriculture to which the people were accustomed naturally developed along the lowlands and in the valleys. The rough, jungle-covered, very rainy, interior regions were not suitable for human habitation nor for agriculture. So the plantations of bananas, bread-fruit, coco-nut, sweet potatoes, taro, and other food crops, were most extensively developed along the lowlands. It soon became evident, however, that many of the lower regions did not receive sufficient rainfall to enable such a moisture-loving plant as the banana to reach its prime. Moreover, the wet valleys, with their copious precipitation and shelter from the strong winds, were recognized as very suitable places for banana groves. This condition led to the establishment of banana plantations throughout the upper valleys and ravines, along the streamways, and in the midst of the rain-forest. The banana plant is tolerant of shade, it can flourish in scant soil, and the coolness of the valleys did not seriously delay the ripening of the fruit.

In this way it came about that a very large proportion of the native banana groves were situated at some distance from the villages, often several miles. The natives went to the groves only to gather the fruit, or to extend the plantings. These groves perpetuated themselves indefinitely, and with the decline of the Hawaiian people became practically "wild" groves. Nowadays, when people speak of the "wild bananas" in the mountains they refer to these groves and to others that have originated from them. They are "wild" in the sense that they have escaped from cultivation, or rather that cultivation is no longer afforded them, and have become thoroughly naturalized; they are not indigenous.

Frequently, in travelling afoot along the narrow and precipitous summit ridges of the older and more deeply eroded mountains of the Hawaiian group, one finds small clumps or groves of banana plants at considerable elevations, 3500 to 4500 feet. In these cold, rainy, summit regions the clumps usually occur on very steep protected leeward slopes, in pockets or in the little hanging valleys that are so characteristic of the older summits. The summit regions of Wai-ale-ale, Ka-ala, Jona-hua-nui, East Molokai, West Maui, and Kohala, all possess these high-altitude banana clumps. The plants are usually somewhat dwarfed in stature, and produce either no fruit whatever, or very small bunches bearing only a few fruits. These scanty fruits are generally eaten by the wild rats as rapidly as they begin to ripen. It is a very rare experience to find ripe bananas in any of the wild groves. In these cold, excessively humid regions the fruits mature very slowly. The bunches are small; often there are not a dozen full sized bananas on the bunch. The plants give every evidence of being in a region too cold and windy for their normal development.

It is difficult to explain the presence of these plants at such elevations, for they are far above the level of the groves tended by the ancient Hawaiians. Yet there is no conceivable agency, save man, that could have originally started these groves at such altitudes. A banana clump can readily propagate itself *down* hill, for the suckers that are broken off or uprooted by storms, fall to lower levels, retain their vitality for a long time, and readily sprout when they lodge in some favorable crevice. This, however, will in no way account for the presence of these isolated clumps near the extreme summits. These regions surely would not have been selected by the primitive Hawaiians as sites for banana groves, for the conditions, as has already been intimated, are highly unfavorable for fruit production.

The banana plant is a gigantic herbaceous perennial, and the green "trunks" or false stems arise from a massive starchy basal corm. In old clumps this basal mass may be 3 or 4 feet in diameter, and several feet thick. It emits great numbers of white, cord-like roots from the sides and lower surfaces. The new shoot-buds originate on the upper surface, at the bases of the older stems or trunks. The life of the basal corm is indefinite; other conditions remaining the same, there seems to be no reason why it could not go on producing new shoots without cessation. In the lowlands and valley floors the corm is hidden beneath the soil, and its relation to the aerial parts is not easily recognized, but up in the mountains, on the steep slopes where there is little soil, the bases are usually exposed, and all parts of the plant may readily be seen.

The plants in many of the deep sheltered ravines and glens are very shallow rooted; one can easily overturn a large plant with a single blow. This condition, combined with the heavy rains and freshets in the mountain streams, results in a continual down-stream migration of banana plants, they are uprooted, wash down stream a few hundred feet or yards, lodge in some angle or corner, sprout and root. In this way the beds of many of the mountain streams, particularly in their upper courses, are marked by clumps of bananas.

Another mode of migration, much slower than the preceding, is that which results from the natural growth of the clump. The shoots that spring up around the margin are crowded outwards at the base as their butts enlarge, and at the tops as their canopies of great leaves unfurl. Thus there is a movement toward the periphery, and the clump slowly spreads into new territory. As the older stems, in the center, fruit and die, young sprouts arise there to replace them, so that the clump is a solid stand of stems in all stages of development.

The native bananas are readily transplanted, and thrive under culture. In Honolulu there are a number of private gardens that contain series of the native varieties, collected in the mountains and on the other islands. The part generally used for propagation is a vigorous plump sucker or offshoot, 2 or 3 feet tall. This is carefully separated from the parent plant, so as not to injure the base of the shoot. It is planted in mellow soil, and usually set deep, half the length of the shoot underground, so that the clump will be deep-rooted and not overturned by the wind. The shoot quickly resumes its growth, and under ordinary conditions will fruit within ten to fifteen months after transplanting.

The trunk or stem of the banana plant is made of petiole bases. These are long, expanded, cellular, and closely ensheath one another. United they form a false stem which is soft and juicy;

a single machete stroke will fell a large plant. The cross-section of the stem reveals the bud of young leaves or fruit in the center, and the progressively older leaves forming successive peripheral envelopments. The long leaf-sheaths that compose the stem are fibrous. This fiber is collected and dried by the natives for the stringing of garlands, etc. In olden times the banana fiber was used in a great many ways, but these ancient practices have fallen into disuse since the introduction of cheap cotton thread and twine. The Hawaiian benana fiber is structurally the same as the "Manila hemp" of commerce, which is obtained from the leaf-sheaths of the Philippine banana, *Musa textilis*.

In ancient Hawaii the large leaf-blades of the banana were commonly used as tablecloths, at the times of the great feasts and carnivals. A quantity of the leaves were gathered and spread out on the ground or mattings. Their clean, smooth, bright green surfaces made an excellent and attractive background for the profusion of the feast or *luau*.

All parts of the banana plant are filled with a watery latex that turns very dark brown or black upon exposure to the air, and forms an indelible stain. This juice was used by the natives in a variety of ways, for marking the *tapa* or bark-cloth, for staining or decorating their household utensils, gourds, etc. This latex may be secured from any part of the plant, but is most abundant in the scape of the young fruit-bunch. If this be severed the cut surface will "bleed" profusely for a long time, and a considerable quantity of the juice may be gathered in this way.

In the ancient regime, when the dreadful *tabu* system was in full force, bananas were among the food prohibited to the women, on pain of death. Bananas, coco-nut, pork, turtle, certain species of fish, etc., were absolutely forbidden for all females, regardless of rank or power. The *tabu* laws were enforced with the greatest rigor. Alexander states that "two young girls of the highest rank, Kapiolani and Keoua, having been detected in the act of eating a banana, their *kahu*, or tutor, was held responsible, and put to death by drowning. Shortly before the abolition of the *tabus*, a little girl had one of her eyes scooped out for the same offense." Until the decadence of the *tabu* system, bananas were rarely eaten by Hawaiian females, and then only under circumstances of the greatest secrecy and danger. The object of these curious food *tabus* seems to have been to reserve the choicer foods for the males alone.

A number of the native varieties are suitable for food only when cooked. These are called "cooking bananas." Heat breaks down the starches into sugars and produces a delicious sugary syrup which saturates the delicate flesh, and gives it the flavor of a dessert or a confection. In modern times these varieties are cooked in a number of different ways—fried, baked, etc.,—but in olden times they were invariably cooked in the Hawaiian underground oven or *imu*. Customarily a number of foods were cooked at the same time, as a matter of convenience and economy. Each kind, fish, pig, bread-fruit, bananas, etc., was wrapped in *ti* leaves. The pit was lined with porous lava stones, which had previously been heated by means of a wood fire built in the pit. When the fire had burned out the pit was lined with *ti* leaves, to protect the food from the hot stones and ashes; the food was put in place; a covering of *ti* or banana leaves was placed over the packages of food; and then all was covered with earth. A small hole was made by means of a stick standing vertically; water was poured into this hole; upon coming into contact with the hot stones it was converted into steam, and thus the food was thoroughly steam cooked. The food remained in the oven for a number of hours,—the time depending upon the quantity of food, etc., then the cover was opened and the food removed. Bananas, as well as other food cooked in this way, attain a delicious and distinctive flavor that does not seem to be secured by any other method. The cooking bananas are in common use among the white people of the islands, and command a good price in the markets. Their popularity is bound to increase steadily, as their merits become more widely known.

As intimated early in this paper, there was an epoch in which the native bananas were suffered to fall into abeyance, but that epoch is now happily past. Much interest has been manifested in recent years in the commercial exploitation of the Hawaiian bananas. It is only a question of time until the best of these valuable and distinctive native varieties will attain a place among the important exports of the mid-Pacific. Certainly the cooking bananas have open before them a field free from competition, and interesting to contemplate from the standpoint of the American dietary. The Hawaiian canned pineapple has developed for itself a phenomenal market, perhaps the native banana will eventually do the same.

# THE IMBIBITIONAL SWELLING OF MARINE ALGAE

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The data obtained by MacDougal as to the swelling of biocolloids composed of agar as a basic carbohydrate and of varying proportions of different nitrogenous substances afford a basis for the interpretation of the general constitution of plant tissues.[1] This was borne out by the results of some swelling tests of marine algae made at the Coastal Laboratory, Carmel, California in July and August, 1917. The results include other points of interest as described below.

*Iridaea laminarioides*, *Gigartina exasperata*, and *G. mammillosa* var. *dissecta*, red algae growing on the rocks near Carmel, were chosen for the tests. These plants have a sap balanced to the imbibition and osmotic pressure of sea-water containing about 3.5% total salts, and the effect of various substances was obtained by adding them to sea water in which sections were to be immersed. Measurements were made by the use of MacDougal's precision auxograph (see table 1).

The imbibition of *Iridaea laminarioides* indicates a high proportion of amino-acids, as shown by the greater swelling in the acidified solutions. *Gigartina*, however, gives measurements indicative of the presence of an agar-like substance, in greatest proportion in mature fronds. This diagnosis is supported by the results of swelling dried material.

Smooth young laminae of *Gigartina exasperata* were washed

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[1] MacDougal, D. T., Imbibitional swelling of plants and colloidal mixtures. Science **44**: 502–505. 1916. The effect of acids and salts on the swelling of biocolloids. Science **46**: 269–272, 1917.

MacDougal and Spoehr, The behavior of certain gels useful in the interpretation of the action of plants. Science. **45**: 484–488, 1917. Growth and imbibition. Proc. Amer. Phil. Soc. **56**: 289–352, 1917. See also reports of the Department of Bot. Research, Carnegie Inst. of Wash. for 1916 and 1917.

TABLE 1

| ALGA USED | THICKNESS | PER CENT SWELLING IN | | |
|---|---|---|---|---|
| | | Sea water plus NaOH N/100 | Sea water HCl N/100 | $KNO_3$ and Citric acid N/100 |
| | *mm.* | | | |
| Iridaea laminarioides | | | | |
| Tip of lamina | 0.4 | 0 | 0 | 537.5 |
| Tip of lamina | 0.4 | 25.0 | 31.0 | 175.0 |
| Gigartina mammillosa var. dissecta | | | | |
| Tip of frond | 0.5 | 10.0 | ? | 60.0 |
| Tip of frond | 0.5 | 50.0 | 15.0 | 60.0 |
| Lateral swelling | | 10.0 | 22.2 | 17.[illegible] |
| Gagartina exasperata | | | | |
| Young lamina (fresh) | 0.6 | 33.3 | 58.3 | 150.0 |
| Young lamina (fresh) | 0.6 | 16.6 | 20.8 | 200.0 |
| Young lamina (fresh) | 0.6 | 12.5 | 50.0 | 158.6 |
| Young lamina (fresh) | 0.7 | 3.5 | 7.1 | 132.8 |

TABLE 2

| ALGA USED | THICKNESS | PER CENT SWELLING IN | | |
|---|---|---|---|---|
| | | Sea water plus NaOH N/100 | Sea water HCl N/100 | Distilled $H_2O$ |
| | *mm.* | | | |
| Gigartina exasperata | | | | |
| Washed and dried young lamina | 0.1016 | 393.7 | 590.5 | 1476.0 |
| | | NaOH N/100 | HCl N/100 | DISTILLED $H_2O$ |
| Same as above | 0.0508 | 2755.9 | 2066.9 | 4330.7 |

TABLE 3

| SUBSTANCE USED | THICKNESS OF SECTS | PER CENT SWELLING IN | | |
|---|---|---|---|---|
| | | NaOH N/100 | HCl N/100 | Distilled $H_2O$ |
| | *mm.* | | | |
| Plates composed of 9 grams agar and extract from 10 grams of dry gigartina exasperata | 0.2286 | 809.0 | 809.0 | 2296.0 |
| Same as above | 0.2032 | 910.4 | 984.2 | 2460.6 |

in fresh running water for twenty-four hours to remove sea salts and then dried between filter papers. Trios of sections of these dried laminae were swelled in $\frac{N}{100}$ HCl, in $\frac{N}{100}$ NaOH, in distilled water and in the sea water solutions mentioned above with results as shown in table 2.

An extraction was made from each of these species by heating several grams of the plants which had previously been washed for twenty-four hours, dried, and finely ground for two or three hours at the temperature of boiling water, and then straining through four thicknesses of muslin. The extract so prepared was a pale straw colored viscous fluid which would not solidify completely when cold but became very thick and viscous. The extract from all of the species was fairly uniform in character. Dried plates were made from 9 grams of agar and the extract from 10 grams of the dry *Gigartina exasperata.* Trios of sections from these plates were swelled (see table 3).

The analysis of the moisture-free material extracted from the alga and extended with the agar gives the following:

| | *per cent* |
|---|---|
| Ash (salts) | 15.89 |
| Gelatine like material | 21.05 |
| Agar-like material | 63.06 |

The washed and dried algae on analysis gave the following:

| | Average values<br>*per cent* | Moisture free<br>*per cent* |
|---|---|---|
| Ash (salts) | 11.70 | 13.89 |
| Moisture | 15.70 | 0.00 |
| Gelatine like material | 14.95 | 17.73 |
| Carbohydrates agar like material | 57.65 | 68.38 |

The swelling of the dried sections, gives figures indicative of the presence of a large proportion of an agar-like substance, a smaller proportion of amino-acids, etc., and salts, and when the extract was mixed with agar the imbibition in water, acid and alkali, conforms to an expectancy of composition based on MacDougal's conclusions of the swelling of biocolloids, which is fully confirmed by the chemical analysis.

## BOOKS AND CURRENT LITERATURE

Woody Plants of Switzerland.—This is the third of a series of studies of the woody flora of Switzerland, each being confined to a single small region.[1] The present refers to the upper Rhine valley, extending from the Upper Alps to Ilanz-Schleuis (Canton Grisons). It is divided into five parts and includes appendix containing a brief bibliography relating to the subject, four phototype plates and two topographic maps on a scale of one mile to the inch. The maps are models for detail, and besides topography indicate in colors and characters all the forest formations even to important single groups of trees. Part I discusses the geography, orography, geology and climate of the region; part II gives a catalogue of the woody plants, so amplified as to contain a description of their botanical and silvical characteristics. A significant feature of the catalogue is the fact that the author adheres strictly to the Linnean nomenclature, in striking contrast to the practice of American botanists to adopt new names. Part III describes the various plant formations, arboreal and herbaceous and their successions and aspects. The herbaceous vegetation characteristic of each tree formation forms an important part of the description. The author compares present forest conditions under each formation with those existing in the primeval forest, using as proof of his idea of original conditions the many sub-fossil forms of wood and fruit he found and the history of the region. Part IV is devoted to the agriculture of the region and the part it played in changing the physiognomy of the forest. In this part he also ties in the success or failure of certain crops with the site factors that control the character of the forest. In part V the results of the study are reviewed.

The work has a scientific interest in that the author does not confine himself to a mere dry statistical presentation of his subject, but explains the ecology of the region and analyzes the factors, both physical and biological, responsible for the present forest and woodland conditions. His studies reveal a profound genetic connection and a close cultural relation between the forest and woodlands, and the pastures, farms and meadows which man had wrested from the primeval forest. The history of the culture of the region is traced back to the seventh century. During the intervening thirteen centuries the handling of the forests, meadows, farms and pastures remained practically stable. The present forest may still be considered natural, since it originated from natural reproduction alone, artificial reforestation dating back only fifty to eighty years and amounting to about 1% of the total. It was, however, profoundly influenced by man, he and his domestic animals having left on the physiognomy of the forest and its boundaries their indelible imprint.

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[1] Hager, P. K. Erhebungen über die Verbreitung der wildwachsenden Holzarten in der Schweiz. Lieferung 3. Gebiet des Vorderrheintales (Kanton Graubünden). Pp. 331, pls. 4, maps 2. Schweiz. Depmt. des Innern, Bern., 1916.

The territory above Ilanz-Schleuis through which the upper Rhine and its tributaries flow, comprises a region of deep alpine valleys and embraces an area of about 300 square miles north of the Central Alps in the western part of the Canton Grisons. The main valley under consideration is about 50 miles long, has an easterly direction and is comparatively straight and broad. On both sides it is flanked by high rugged mountain ranges, many of whose canyons head in permanent glaciers. The elevation of the upper Rhine at Tschamut near the upper and west end of the valley is about 5400 feet above the sea level, while at Ilanz, the eastern boundary of the region under study, it has descended to 2300 feet. The elevation of the enclosing mountains is from 9000 to 11,000 feet above sea level. The average annual precipitation in the valley varies from 39 inches to 45 inches, the average monthly during the growing season, March to September, being 3.5 inches to 4.0 inches. Moist south and southwest winds bring in this large precipitation. The winter snowfall is heavy and much damage is done through snow pressure both in the forests and in the orchards. The author speaks of our own black locust, planted for ornamental purposes, as withstanding the winter snows only with difficulty.

The author presents ample evidence that the region was once heavily forested and that the forest was made up of a number of strongly individual types according to exposure and soil and moisture conditions. Besides forests there were originally open grassy "parks" and heaths, which exist in part today. At present the forest cover is only fragmentary. The phototype plates in the appendix give a very vivid picture of this condition. Farms and pastures now occupy sites which were once heavily timbered. Man cleared the benches having southern exposures before he attacked the valley. These benches are now largely abandoned.

Originally the valley meadows consisted of associations of *Agrostis*, *Phragmites* and *Typha*, and were entirely free from conifers. Now alders and willows contend for control, while occasional Scotch pines obtain a foothold.

The broad leaved or hardwood forests, whose predominant species are *Quercus sessiliflora* and *Fagus silvatica*, occupy the lower slopes of the mountains. Their altitudinal range is from 2300 feet to 4200 feet above sea level. No well defined line divides the hardwood forest from the coniferous forest. Other hardwoods—birch, cherry, alder, sorbus and others are found along with some conifers mixed in with the oak and beech, giving the forest a mixed aspect. Oak is more typical of south slopes, while beech prefers north slopes. Oak bears fertile seed at 4200 feet, but where it is scattered at higher elevations it is only in occasional years that fertile seeds are borne. This gives one reason why the author believes the original upper limit of this hardwood forest to have been higher than it is now. On north slopes spruce, (*P. excelsa*) and fir (*A. alba*) compete with the hardwoods, while on the south slopes Scotch pine (*P. silvestris*) endeavors to establish itself. Notwithstanding the intrusion of these conifers the forest is essentially one of hardwood species. Birch, although it makes no pure forest anywhere, is widely scattered throughout the forest. The hardwood forest suffered much greater change through the intrusion of man than the higher coniferous forests. Only comparatively small patches of it remain, the rest being taken up by hill farms and pastures. Collectively, however, there is still abundant hardwood timber of good size.

From 4200 feet to 4700 feet the forest has the aspect of a transition type, merging the hardwood belt with the subalpine coniferous forest, whose upper limit in turn is given as 7000 feet. This coniferous forest consists on the south exposures of more or less stunted Scotch pine and mountain pine (*P. montana*), and on the north exposures of spruce, white fir and large mountain pine, while according to the site, may be found in mixture scattering specimens of birch (*B. betula*), aspen (*P. tremula*), alder (*A. viridis*), willows, mountain ash (*S. aucaparia* and *S. aria*) and sycamore (*Acer pseudoplatanus*). From 7000 feet to about 7500 feet the forest gradually approaches timber line, and the subalpine herbaceous flora becomes prominent. About timber line and up to about 8800 feet flourish alpine grasses and ericaceous shrubs, such as rhododendron and vaccinium with which are mixed some juniper (*J. communis*).

The studies indicate that because of the advent of man and his domestic animals, hardly a single forest type, except perhaps the higher alpine, escaped considerable disturbance. Both the horizontal and altitudinal distributions of species and types have been perceptibly altered. The altitudinal limit of the sub-alpine zone is said to have been lowered 800 feet, mainly because of fire and cutting. Alpine grass lands have in this way been extended. Succession in this zone is interesting. Recent clear cut areas are appropriated by alder (*Alnus viridis*) wherever the site is favorable to the species. This formation remains permanent if it is cut periodically or where it is strongly influenced by grazing. Without these two factors operating, the alder type is simply a phase of the succession tending to bring about a new forest of conifers. The various successions take place in a relatively short space of time after cutting. First occurs the occupation of the area by alder and scattering willows, birches, aspens, mountain ash and maple, then comes a slow but steady advance of young conifers followed by a disappearance of the temporary hardwood cover, and finally a renewal of the original coniferous type. Within the present openings on which are rhododendron and vaccinium, conifers attempt to crowd in under the protection offered by the shrubs. However, if they are not trampled and browsed by stock and attain size, they are cut down by alpine settlers or destroyed by fires set by willful herders.

The influence of man and cattle in changing the distribution of species is impressive. It is reflected in a surprising uniformity in extended spruce forests, the presence of other conifers only as admixtures and the decrease of the once prominent white fir through management favoring the more valuable spruce, although white fir possesses very strong reproductive energy and is a vigorous competitor for control. Scotch pine is now intermixed on the south slopes as a subordinate tree, but since 1901 it has been used considerably in artificial restocking. Heavy cutting combined with low temperatures have mitigated against this pine in the upper valley. It attempts to invade the valley meadows, but seldom wins against the competition of the alders and willows. The distribution of larch (*L. decidua*) is now conspicuously light compared to its former abundance in mixture with *Pinus cembra* on forest borders due largely to destructive management made more serious because of the tree's great intolerance of shade. Larch and *Pinus cembra* are now being used in artificial reforestation. Until strict modern forest regulation and management was instituted by the state, the forests of the region were grossly mismanaged, unregulated clear cutting being the rule.

The influence of man on the distribution of hardwoods is even more noticeable than among the conifers. Most important, the hardwood forests being in the zone of husbandry had to give way rapidly to cultivation; furthermore, they suffered severely because of a shortsighted and wasteful management of what was not cleared. There followed also as a consequence an extension downward of the coniferous zone brought about by the release of conifers from competition with the hardwoods where the two were in mixture. In contrast to the restriction of the hardwood forest due to cultivation is the extension and spread of single species over a wide area, the habit of alder in particular in invading newly cut coniferous forests in the sub-alpine zone being a good example.

As a thorough piece of work Dr. Hager's contribution deserves commendation. Considering the area under investigation, only about 300 square miles, his book of over 300 pages seems hardly warranted from an American point of view until one considers the more intensive relationship existing between man and his surroundings in an old country like Switzerland. The work should be of value to the student of ecology as well as the student of scientific forestry.—EMANUEL FRITZ.

SPECTRAL COLOR AND STIMULATION.—The paper under notice[1] is a continuation of a series of studies in light response of lower organisms which, although more largely concerned with algae than the lower animals, are unfamiliar to most botanists since the results have been published in zoological periodicals. In the author's previous studies he found that in a field of white light consisting of two beams crossing at right angles, the organisms proceeded towards or away from a point situated between the two beams; the location of this point being dependent upon the relative effectiveness of the two beams. The present series of experiments is based upon the assumption that if an organism exposed to light from two sources proceeds towards or away from a point midway between the two, the light received from the two sources is equal in stimulating power no matter how it may differ in quantity or quality. Knowing the wave length of the beams of light producing the field of illumination it is possible to compare the stimulative effect of rays of light of different wave length.

Although a large number of investigators have studied the effect of different qualities of light upon plants but few have taken up the question of the relative stimulating efficiency of light rays of different wave length. The various observations on the effect of light upon plants have been admirably summarized in tabular form by the author.

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[1] Mast, S. O. The relation between spectral color and stimulation in the lower organisms. Jour. Exp. Zoöl. **22**: 471-528. 1917.

The algae studied include various *Euglena* species, *Phacus triqueter*, *Trachelomonas euchlora*, *Chlamydomonas globulosa*, *Gonium pectorale*, *Pandorina morum*, *Eudorina elegans* and *Spondylomorum quaternarium*. In all of these forms certain spectral colors are much more effective as stimulating agents than others. Thus for *Pandorina morum* (table 10, p. 509) the greatest response, calculated on the basis of equal energy, is found in light rays 524 $\mu\mu$ long, the response diminishing rapidly on either side of this point in the spectrum. This is correlated with the luminous intensity, for if light on either side of the maximal point in the spectrum is sufficiently intense it is more effective than the light at the maximum. In any species the distribution of the response to rays of different wave length is the same regardless of changes in physiological condition, environment, or nature of response. The curious point brought out by these investigations is, however, that the maximum is practically the same for certain species that are not closely related (*Euglena* and *Gonium*) while closely related species (*Gonium* and *Pandorina*) do not necessarily have the same maximum.

The experiments were carried out in the Nela Research Laboratory of the General Electric Company and the assistance which a purely commercial company has given to a study of this type, which has no apparent commercial value, is worthy of commendation by all scientists.—GILBERT M. SMITH.

THE STRAWBERRY IN NORTH AMERICA.—Of particular interest to horticulturists is the new work on the history, origin, botany, and breeding of strawberries.[1] There have been several attempts to trace the origin of our cultivated strawberries of today. In his review of the subject in 1896, L. H. Bailey remarked that "Perhaps there is no other plant which has more quickly obscured its own origin." The author of the present work agrees with previous writers that three species make up the possible foundation stock of our present varieties: *Fragaria virginiana*, the common wild strawberry of Eastern North America; *F. chiloensis*, the Chilean berry native to the Pacific coast of both North and South America, and *F. ananassa* the pineapple or pine strawberry which appeared rather mysteriously in Europe in the middle of the eighteenth century. Apparently no wild prototype of this pine strawberry has ever been found and as it was destined to play a very important part in strawberry breeding, its origin becomes a matter of considerable interest. In "Survival of the Unlike," L. H. Bailey, after a painstaking study, puts aside the theory of a hybrid origin, and concludes that variation induced by the change of environment from Chili to Europe resulted in the direct development of the pine from the Chilean, and hence the blood of *Fragaria chiloensis* if not pure at least preponderates in our present varieties. Fletcher, in the work under review, marshalls a number of facts and arguments in support of the older idea that the pine strawberry was a hybrid between *L. virginiana* and *F. chiloensis*. He brings into more prominanee the historical fact that the original importation of five plants of *F. chiloensis* taken from Concepcion, Chile to Brest, France by Frezier in 1712 were all pistillate and that inasmuch as a number of hermaphrodite varieties of *F. virginiana* had already been growing in European gardens for a hundred years, the origin of the pine strawberry as a chance hybrid between these two species is well within the range of probability.

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[1] Fletcher, S. W. The strawberry in North America. Pp. xiv + 234, figs. 26. The Macmillan Company; New York, 1917 ($1.50).

In the chapter on breeding, page 213, we note the following: " 'Pedigree' strawberry plants have not proved to be permanent departures from the type of the variety . . . . It is evident that few if any, permanent varieties may be expected from this source. . . . It would be better if they were sold for what they really are—selected, not 'pedigree' plants."

On the whole, Dr. Fletcher's book forms a welcome addition to the literature of American horticulture.—J. Eliot Coit.

## NOTES AND COMMENT

An informal meeting of editors of botanical journals was held at Pittsburgh on December 28, in response to a call from Dr. Donald Reddick, to consider the feasibility of founding an American journal for the publication of abstracts of the currrent botanical literature of the world. So much interest was expressed by the thirteen men present that it was decided to hold a meeting on December 30 and to invite all of the botanical societies gathered at Pittsburgh to send representatives to it for a further discussion of the project. At the second meeting a feeling was unanimously expressed that a journal of botanical abstracts would be of great value to all botanists and that its financial support would not present serious difficulties. Considerable time was spent in discussing means of providing funds for the journal, and in settling upon some of the most important features of its format, typographical style and contents.

This meeting of twenty-five men formally organized as a Committee on Botanical Abstracts, and took measures for its own perpetuation by the appointment of two members from each of the societies devoted to botanical subjects. A Board of Control was elected by ballot, consisting of ten men charged with the immediate prosecution of plans for Botanical Abstracts. These men are: Donald Reddick, Chairman, J. H. Barnhart, H. C. Cowles, B. M. Duggar, C. Stuart Gager, R. A. Harper, B. E. Livingston, F. C. Newcombe, C. L. Shear, and Forrest Shreve. The Board of Control held several meetings during the last days of Convocation Week, drew up the specifications for the journal and planned for the apportioning of the abstracting and editorial work. The inviting of foreign coöperation in the administration of the journal was deferred to a more propitious time, on the motion of Prof. A. H. Reginald Buller, of Winnipeg. Dr. B. E. Livingston was appointed Editor-in-Chief, a position which he agreed to accept without emolument. Associate Editors were chosen as follows for fifteen subdivisions of botanical science; Agronomy and Soil Technology, R. W. Thatcher; Bacteriology, H. J. Conn; Botanical Education, C. Stuart Gager; Cytology, C. J. Chamberlain; Ecology and Plant Geography, H. C. Cowles; Forestry, I. W. Bailey; Genetics, George H. Shull;

History, biography and bibliography, J. H. Barnhart; Horticulture, W. H. Chandler; Morphology, E. W. Sinnott; Paleobotany, E. W. Berry; Pathology, Donald Reddick; Pharmacognosy, Henry Kraemer; Physiology, B. M. Duggar; Taxonomy, William Trelease, J. M. Greenman, J. G. Schramm.

The results of work on the natural reproduction of Douglas fir and western white pine have recently been published in the Journal of Agricultural Research by Mr. J. V. Hofmann. Investigations carried out in Washington, Oregon and Idaho indicate that the reappearance of these trees after a burn is chiefly due to the germination of seeds buried in the deep litter of the forest floor. Seed trees are unable to restock the forest for a distance of more than 300 feet. A second burn, destroying trees too young to have shed seed, results in a severe check to forest reproduction. The findings presented in this paper are of considerable importance in the theoretical discussion of succession as well as in their bearing on forest management in the northwest.

A Flora of the Rocky Mountains and Adjacent Plains has just appeared from the hand of Dr. Per Axel Rydberg, of the New York Botanical Garden. The work covers Colorado, Utah, Wyoming, Idaho, Montana, Saskatchewan, Alberta, and parts of Nebraska, South Dakota, North Dakota and British Columbia. It contains 1110 pages and is privately published by the author (price $3.75).

Mr. V. C. Finch and Dr. O. E. Baker have prepared a publication entitled Geography of the World's Agriculture, which will appear at an early date as a Contribution from the Office of Farm Management of the Department of Agriculture. It will be a book of 150 pages, abundantly illustrated with maps showing the quantitative distribution of the leading agricultural products of the world.

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# The Plant World

A Journal of General Botany

VOLUME 21
NUMBER 2
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# RAUNKIAER'S "LIFE FORMS," "LEAF-SIZE CLASSES," AND STATISTICAL METHODS

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## I. TRANSLATORS' NOTE

The importance of the work of C. Raunkiaer in giving needed emphasis to the study of the perennial vegetative organs of plants is too well appreciated to require comment. His publication in the Danish language tended to prevent American ecologists from becoming familiar with his "life-forms" until his various papers upon the subject were so well summarized by Smith.[1] The subsequent appearance of two articles dealing with similar topics seemed to make it desirable to give his suggestive ideas wider publicity by preparing the following somewhat abridged translation. This was made possible only through the knowledge of the Danish language possessed by the junior author.

As it has not been practicable to obtain Raunkiaer's approval and revision of this article the translators accept full responsibility for any errors of interpretation or expression that may occur but they trust that such inaccuracies may in no way detract from the understanding and appreciation of these methods of the quantitative study of vegetation.

## II. LEAF-SIZE IN PLANT GEOGRAPHY[2]

In order to compare the value of various phenomena, the material under investigation must be brought under similar

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[1] Smith, W. G., Raunkiaer's Life-forms and statistical methods. Jour. Ecol., **1**: 16–26. 1913.

[2] Raunkiaer, C., Om Bladstørrelsens Anvendelse i den biologiske Plantegeografi. Bot. Tidsk. **33**: 225–240. 1916.

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FEBRUARY, 1918

conditions and while I would not say that we must always express our results numerically it is evident that where scientific comparisons are undertaken we should be able to present phenomena mathematically or in terms that are as definite and unmistakable as numbers. In the field of biology, where there are so many complexities of form and character, it is often a difficult matter to measure, or estimate with exactness the value of a single character and thus determine its significance.

Ecology is one of the most difficult branches of botany in this particular, not from any specific peculiarity, but because it embraces all the relations and all the difficulties of botany taken as a whole. Thus every student of botany is concerned with ecology because it includes plant behavior under all existing conditions.

The factor most frequently emphasized in ecology is that of water. During the last forty years, especially during the last quarter of the nineteenth century, plants have been classified according to their water relations. They exhibit variations of structure which serve to protect them against excessive transpiration and hence they exist in habitats where excessive evaporation occurs, or where absorption of water is difficult, either because of physical or physiological factors.

These variations of structure are such things as (1) protective coverings, (2) thick epidermis, (3) hypodermal tissue, (4) water storage tissue, (5) coverings of hairs, (6) protective devices for stomatal openings, (7) depression of stomata, (8) pits enclosing the stomata, and (9) a decrease in the area of leaf surface exposed.

Again it is apparent from the nature of the case that it is a difficult matter to reach an exact conclusion based upon the biological (ecological) characters of a single plant community. The members of such a community existing under arid conditions are some of them present on account of acquired characters of one sort while others exist because of quite different adaptations and we cannot obtain the quantitative value of a single character or of a single group of characters.

In general it is sufficient to observe the outstanding character without proceeding with a statistical study of it as related to the environment. A statistical investigation for the purpose of ascertaining the importance of a single character, to be successful, must be directed so as to treat the xeromorphic characters of various plant societies in exactly the same way.

A comparison of a series of evergreen phanerophytic communities, such as a tropical rain forest, a mesophytic tropical evergreen forest of the West Indies, and a thicket (Maquis) of the Mediterranean region reveals among the various adjustments a decrease of the transpiring surface, a decrease in leaf-size, as one of the main features. This character not only plainly evident, but also comparatively easy to measure, and is readily accessible for the application of statistical methods. And yet difficulties are encountered in such an investigation.

What shall be the units measured? The leaves, the physiollogical units that are present, correspond to the morphological units, but shall we compare the simple leaf with the leaflet of a compound leaf or with the entire leaf? If we compare the simple leaf with the compound leaf of the same life-form in the same community, as for example, the canopy of the East Indian deciduous phanerophyte forest, we find that the compound leaf generally is much larger than the simple leaf, and belongs to higher "size-class" than the latter, hence the leaflet is more nearly comparable in size to the simple leaf, even if some of the leaflets are somewhat smaller. Consequently, it naturally follows that the leaflet is to be regarded as the biological unit rather than the compound leaf.

A still greater difficulty is encountered in dealing with the lobed leaf, which presents all variations from the simple to the compound, but we shall regard the lobed leaf without further discussion as a simple leaf. Neither is it as easy as it might appear to determine the proper place of lacerated and dissected leaves: in some cases it seems natural to regard the whole leaf as a unit, in other cases a single lobe, and in still others a series of lobes seem to constitute the unit, which must be compared with the simple leaf.

Considering the difficulties mentioned above, before we make use of the variations in leaf size to characterize a given formation we must distinguish between and determine the number of:

1. Species with simple (including lobed) leaves,
2. Species with (a) lacerated leaves and (b) dissected leaves.

It is apparent that the size of the three groups will give some interesting data concerning the formation under consideration.

It is necessary to treat every life-form by itself; for example, the evergreen cannot be treated in the same group with the deciduous mesophanerophyte, etc. After the material is divided into groups, according to their life-forms, the "leaf-size" of each species in all the groups, or in one or more of them, depending upon which are the most important, is determined.

If the arborescent vegetation of a tropical phanerophyte formation is examined and found to consist of (1) 1% deciduous phanerophytes, (2) 99% evergreen phanerophytes, in which (a) 9% have compound, lacerated and dissected leaf-blades, (b) 90% have simple (including lobed) leaves, then the first thing will be to determine the "leaf-sizes" of the species in this last and largest group.

It will be easier and more significant to investigate the group or groups with the simple (including lobed) leaves for generally these will be far the most numerous in all phanerophyte and chamaephyte formations. Consequently I shall confine attention to this group and determine the "leaf-size" for every species.

An exact determination of the area of leaf surface cannot be undertaken because the leaves of the same plant will vary more or less in size and also because such measurements would take much longer than the importance of the results would warrant, rather in all practical comparisons of leaf-size it will be necessary to separate the leaves into a number of classes according to size; and for all ordinary cases there must not be too many classes. It should be very easy, from the very outset, to refer a plant to the proper class based upon "leaf-size."

The primary questions are: (1) How many "size-classes?' and (2) What are their limitations? I am in favor of a few classes only for general comparisons; these may be subdivided when necessary, and I have decided upon six "size-classes" proceeding from the smallest to the largest blade, and have given the following names which may be used as adjectives as well as nouns: Leptophyll, Nanophyll, Microphyll, Mesophyll, Macrophyll, and Megaphyll.

In determining the limits of a single class I took a progressive series of dry leaves varying much in size, and separated them tentatively into six classes. I placed them upon millimeter paper and carefully noted where the boundary between the six classes could be set. I also persuaded a number of botanists among my colleagues to consider the same problem. The result has caused me to set the upper limits of the lowest "size-class," Leptophylls, at 25 square millimeters. Five consecutive multiplications by 9 give products that respectively cover all the material. The limits between the various classes are represented accordingly:

1. Leptophyll, 25 sq. mm.
2. Nanophyll, $9 \times 25$ sq. mm. = 225 sq. mm.
3. Microphyll. $9^2 \times 25$ sq. mm. = 2,025 sq. mm.
4. Mesophyll, $9^3 \times 25$ sq. mm. = 18,225 sq. mm.
5. Macrophyll, $9^4 \times 25$ sq. mm. = 164,025 sq. mm.
6. Megaphyll.

Originally I multiplied by 10, but the resulting limits between the "size-classes" did not seem as natural as when 9 was used. It is easy in the final analyses to separate the single classes into the groups of small, medium, and large. As shown by the diagrams (fig. 1) I have produced a graphical scheme whereby the leaf-size is indicated as well as the limit between the different classes. The leaf blade which is smaller than figure a (25 sq. mm.) is a leptophyll; that which lies between figures a and b ($9 \times 25$ sq. mm.) a nanophyll; between b and c ($9^2 \times 25$ sq. mm.) microphyll. The size represented by the limits between macrophyll and megaphyll gives a dimension that is practically 8 times the size of the entire figure.

Usually, by a comparison with these standards, it will be an easy matter to determine the class to which a certain leaf be-

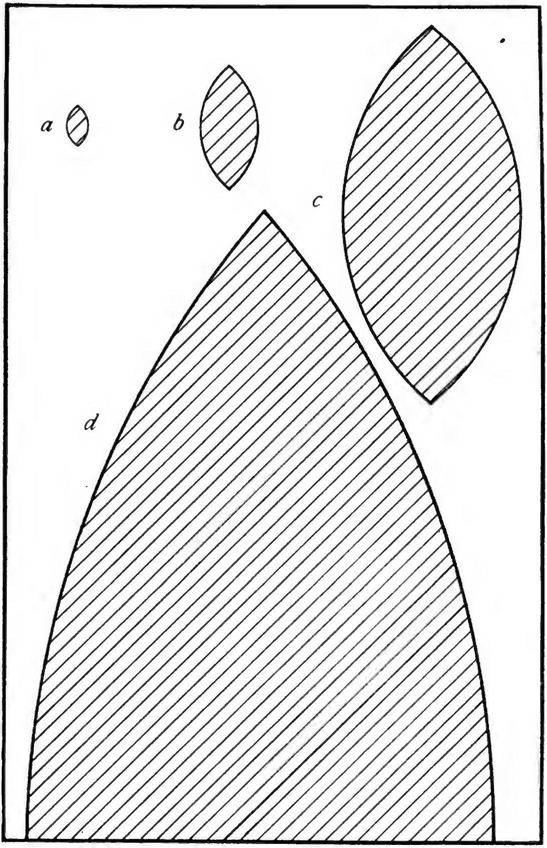

Fig. 1. Graphical representation of the limits between the different "leaf-size classes." Leaves smaller than *a* are leptophylls; between *a* and *b* nanophylls; between *b* and *c* microphylls; between *c* and twice *d* mesophylls; between twice *d* and eight times the area of the entire figure macrophylls and all larger leaves are megaphylls.

longs. We shall even be able in the majority of cases to obtain the correct size without the assistance of the plate. A plant whose leaves are distributed between nanophylls and microphylls may be regarded as a nano-microphyll, etc. If we wish in a given case to determine exactly where a leaf belongs, we can make use of paper whose weight per square centimeter is known and from it cut out the leaf area, weigh the same and compare its weight with the weight of same paper which corresponds to the limit between microphyll and mesophyll; namely, 2025 sq. mm.

As to the advantages of this method, I would say that in this way we can easily interpret climatic factors in terms of leaf-size, and we can compare conditions in two climatic areas whose responses to climate differ in some outstanding particular, such as, for example, that of bud protection, below the surface of the substratum (in life-form), and demonstrate that the climatic differences give a variation in leaf-size. We may also note whether the variations exist when we investigate the vegetation of countries with similar climates but with flora composed of different species.

We may investigate by this method formations which vary in different areas but in which the organisms are so similar that the various formations have assumed a common aspect, and we here possess the means of determining to what extent the reaction is different in so far as its character is revealed in leaf-size. I shall endeavor to illustrate this by a few examples, comparing several European evergreen scrub formations. These examples are taken from those I have investigated by statistical (valence) method. In a given formation it is necessary to determine first the degree of frequency of a species and use this index as a foundation for the comparison, and thus significant and reliable results may be obtained.

As examples of evergreen shrub formations, I have chosen: (1) a west Jutland heath—*Calluna vulgaris* formation, (2) a marquis or thicket (Garigue) in southern France, *Erica multiflora* formation, (3) a mountain maquis in northeastern Spain, *Arbutus unedo* and *Quercus coccifera* formation, (4) a thyme heath upon the dry hills of the interior of northern Spain, *Thymus hiemalis* formation.

These four formations were examined by the "valence method." Results are given in tables 1, 2, 3 and 4. These tables show the characteristics of the formations in question in so far as nanophanerophytes and chamaephytes are concerned. For the west Jutland heath and the southern France maquis there are also included species representing the phanerogamous flora as a whole. This is not the case with the formations from northern Spain where the phanerophytes and chamaephytes only are in evidence. There is no similarity between the small shrubs and the remaining life forms. It is certain that these are essentially shrub formations; formations in which the nanophanerophytes and chamaephytes predominate.

In tables 1 to 4 the dominant species of the formation are given in order of importance, and the other species are arranged alphabetically. In the first column after the name of the species the "life-form" to which the species belongs is given, in the second the species' valence in terms of per cent, and finally in the third column there is given the "size-class" of all the simple (including lobed) leaved evergreen phanerophytes and chamaephytes.

The tables show four formations differing in various ays. The nanophanerophytes and chamaephytes dominate most completely in the *Calluna vulgaris* formation, the poorest in number of species possessing 5 only; then follows the *Thymus hiemalis* formation with 7 species; the *Arbutus unedo* and *Quercus coccifera* formations with 12 species, and the *Erica multiflora* formation with 22 species. The sum of the valence numbers of the nanophanerophytes and chamaephytes shows the *Thymus hiemalis* formation standing first. Arranged according to a physiological viewpoint, that is, according to the height of the vegetation, the *Thymus hiemali* is lowest, then follows *Calluna vulgaris* and finally the most vigorous *Arbutusunedo* and *Quercus coccifera.*

We shall now inquire whether a significant comparison upon the basis of leaf-size can be made between evergreen phanerophytes and chamaephytes with simple (including lobed) leaves. From the facts shown in tables 1 to 4 and from the percentage both of number of species and valence of species of phanerophytes and chamaephytes with entire (and lobed) leaves compared with the total number of those forms in each of the four formations, the data shown in table 5 are obtained. We at once see that the life-forms in question (evergreen phanerophytes and chamaephytes with simple leaves) are dominant in number of species, constituting from 58 to 80% of the phanerophytes and chamaephytes in the four formations, but when we take cognizance of the species valence, then this dominance becomes more evident and the percentages lie between 82 and 99.5, hence it appears that the formations are more nearly alike than would be indicated by the comparative number of species. The four formations are therefore very closely related in the dominance of evergreen phanerophytes and chamaephytes with simple (including lobed) leaves. It is therefore appropriate to undertake to compare the "leaf-size" in the "life-forms" of the four formations and to attempt to characterize them in that respect.

In tables 1 to 4 the last column gives the "leaf-size-class" to which each of the species with which we are concerned belongs, and by means of the species' valence per cent in column 2 we are able to determine the relative importance of the leaf-size-classes in the formations.

In the *Calluna vulgaris* formation there are two species that are nanophyll, namely, *Arctostaphylos* and *Vaccinium vitis-idaea*, making with the valence per cent 14 points; two species, *Calluna vulgaris* and *Empetrum nigrum* are leptophyll, giving together 188 points, that is, the nanophylls constitute 7% and the leptophylls 93% in the formation. In the *Thymus hiemalis* formation all the species are leptophyll, hence it is 100% leptophyll. In a similar manner the *Erica multiflora* formation shows 21% nanophyll and 79% leptophyll. In the *Arbutus unedo, Quercus coccifera* formation (table 4) we have three leaf size-classes; namely, 59% microphyll, 27% nanophyll and 14% leptophyll. It must be noted that *Cistus salviaefolius* is regarded as a microphyll. It is often placed between microphylls and nanophylls and if we consider its valence percent as added both to the microphylls and nanophylls in our calculations, a slightly different value is obtained; namely, 48% microphyll, 40% nanophyll and 11% leptophyll; but it does not conceal the fact that the characteristic of this formation is the relatively large leaf size.

The result of this investigation of leaf-size in the four formations is summarized in table 5, where the formations are grouped

TABLE 1

*Statistical-biological analysis of the Calluna-Empetrum heath on the hills (hill-island) in West Jutland (100 areas of 0.1 sq. m. each)*

| | LIFE-FORM | DEGREE OF FREQUENCY OR VALENCE PER CENT | LEAF-SIZE OF THE EVERGREEN PHANEROPHYTES AND CHAMAEPHYTES WITH SIMPLE (AND LOBED) LEAVES |
|---|---|---|---|
| *Calluna vulgaris* | Ch | 98 | 1 |
| *Empetrum nigrum* | Ch | 90 | 1 |
| *Arctostaphylos uva-ursi* | Ch | 11 | n |
| *Vaccinium uliginosum* | N-Ch | 1 | |
| *Vaccinium vitis-idaea* | Ch | 3 | n |
| *Carex Goodenoughii* | G | 1 | |
| *Carex panicea* | G | 1 | |

TABLE 2

*Statistical-biological analysis of the Thyme formation upon a hill slope 2 km. east of Lerida (50 areas of 0.1 sq. m. each).*

| | LIFE-FORM | DEGREE OF FREQUENCY OR VALENCE PER CENT | LEAF-SIZE OF THE EVERGREEN PHANEROPHYTES AND CHAMAEPHYTES WITH SIMPLE (AND LOBED) LEAVES |
|---|---|---|---|
| *Thymus hiemalis* | Ch | 100 | 1 |
| *Fumana glutinosa* | Ch | 4 | 1 |
| *Genista scorpius* | Ch | 2 | |
| *Helianthemum hirtum* | Ch | 6 | 1 |
| *Santolina chamaecyparissus* | Ch | 6 | |
| *Siderites hirsuta var. tomentosa* | Ch | 2 | 1 |
| *Teucrium polium* | Ch | 4 | 1 |

### TABLE 3

*Statistical-biological analysis of the Erica-multiflora formation in South France (50 areas of 0.1 sq. m. each)*

| | LIFE-FORM | DEGREE OF FREQUENCY OR VALENCE PER CENT | LEAF-SIZE OF THE EVERGREEN PHANEROPHYTES AND CHAMAEPHYTES WITH SIMPLE (AND LOBED) LEAVES |
|---|---|---|---|
| *Erica multiflora* | N | 68 | l |
| *Amelanchier vulgaris* | N | 2 | |
| *Daphne gnidium* | N | 2 | n |
| *Genista scorpius* | N | 28 | |
| *Juniperus* sp. (*communis*?) | N | 4 | l |
| *Lavandula vera* | M | 18 | n |
| *Rosa sepium* | N | 2 | |
| *Rosmarinus officinalis* | N | 46 | n |
| *Arenaria capitata* | Ch | 6 | l |
| *Artemisia campestris* | Ch | 2 | |
| *Coris monspeliensis* | Ch | 26 | l |
| *Cytisus argenteus* | Ch | 12 | |
| *Fumana procumbens* | Ch | 68 | l |
| *Helianthemum hirtum* | Ch | 2 | l |
| *Helianthemum polifolium* | Ch | 38 | l |
| *Helichrysum stoechas* | Ch | 20 | l |
| *Ononis minutissima* | Ch | 26 | |
| *Satureia montana* | Ch | 10 | |
| *Sedum anopetalum* | Ch | 2 | l |
| *Sedum nicaeense* | Ch | 12 | n |
| *Teucrium marum* | Ch | 6 | l |
| *Thymus vulgaris* | Ch | 50 | l |
| *Anthyllis vulneraria* | H | 10 | |
| *Aphyllanthes monspeliensis* | H | 22 | |
| *Asperula cynanchica* | H | 16 | |
| *Avena bromoides* | H | 12 | |
| *Carex Halleriana* | H | 14 | |
| *Euphorbia serrata* | H | 10 | |
| *Festuca ovina* | H | 56 | |
| *Festuca ovina* | H | 56 | |
| *Globularis vulgaris* | H | 2 | |
| *Hieracium pictum* | H | 18 | |
| *Hypochoeris radicata* | H | 2 | |
| *Psoralea bituminosa* | H | 6 | |
| *Schoenus nigricans* | H | 2 | |
| *Stipa juncea* (?) | H | 20 | |
| *Taraxacum gymnanthus*? | H | 2 | |
| *Trinia dioeca* | H | 24 | |
| *Brachypodium ramosum* | G? | 4 | |
| *Cirsium* (*arvense*?) | G | 2 | |
| *Aethionema saxatile* | Th | 2 | |
| *Asterolinum stellatum* | Th | 2 | |
| *Cuscuta* sp. | Th | 10 | |

TABLE 4

*Statistical-biological analysis of the Arbutus unedo formation, Barcelona (50 areas of 0.1 sq. m. each).*

| | LIFE-FORM | DEGREE OF FREQUENCY OR VALENCE PER CENT | LEAF-SIZE OF THE EVERGREEN PHANEROPHYTES AND CHAMAEPHYTES WITH SIMPLE (AND LOBED) LEAVES |
|---|---|---|---|
| *Arbutus unedo* | N | 96 | mik |
| *Calycotome spinosa* | N | 22 | |
| *Cistus salviaefolius* | N | 62 | n.-mik. |
| *Erica arborea* | N | 38 | l |
| *Lonicera caprifolium* | N(-Ch) | 14 | |
| *Phillyrea media* | N | 2 | mik. |
| *Pistacia lentiscus* | N | 4 | |
| *Quercus coccifera* | N | 76 | n |
| *Quercus ilex* | M(-N) | 2 | mik. |
| *Quercus pubescens* | N | 2 | |
| *Smilax aspera* | N | 4 | mik. |
| *Dorycnium suffruticosum* | Ch(-H) | 2 | |

TABLE 5

| | NANOPHANEROPHYTES AND CHAMAEPHYTES | | EVERGREEN N AND Ch WITH SIMPLE (AND LOBED) LEAVES | | | | |
|---|---|---|---|---|---|---|---|
| | Number of species | Points | Percentage comparison of N and Ch with reference to | | Percentage of leaf-size classes based upon species valences | | |
| | | | Number of species | Frequency | Mic. | Nan. | Lept. |
| *Thymus hiemalis formation* | 7 | 124 | 71 | 92 | | | 100 |
| *Calluna vulgaris formation* | 5 | 203 | 80 | 99.5 | | 7 | 93 |
| *Erica multifiora formation* | 22 | 450 | 68 | 82 | | 21 | 79 |
| *Arbutus unedo and Quercus coccifera formation* | 12 | 324 | 58 | 86 | 59 | 27 | 14 |

according to height. It is noticed that the similarity is greatest between the heath of West Jutland and the Thyme of northern Spain. We see here that in climates differing largely in a physical sense the same life forms may appear. As far as the heath is concerned, it is leptophyll, its xerophytism as a whole being due to the physiological dryness of the winter, while the determining factor in the *Thymus* formation is the actual dryness of the summer. If we examine the species we can easily see that the two formations belong naturally to two different climates, for in the *Thymus hiemalis* formation many therophytes are developed in a favorable spring. On the other hand it may be remarked that within a single community we have such a limited area that the explanation may not lie with climate alone.

The *Erica multiflora* formation is by far richer in species than the *Calluna vulgaris*, but in a biological sense does not differ materially from it. The most widely separated from the heath is the *Arbutus unedo* and *Quercus coccifera*, both of which are much taller and possess larger leaves.

In table 5, the formations are arranged according to their height, the tallest at the bottom; it seems as if the decrease in height is accompanied by a decrease in the leaf size.

Here is shown a reliable basis for comparing and showing the connection between closely related formations. It is especially important in cases like that of the Mediterranean region where the Maquis is the dominating type of formation, of wide-spread occurrence and exhibiting many variations in floristic composition. By means of the statistical method these variations may be accurately determined and comparisons instituted regarding each character and adaptation which can be, in some way or another, expressed in terms of numerical value, as has been done with reference to leaf-size. The same thing may be done with reference to the protection of the stomatal openings, dimension of stomatal openings, thick cuticle, hairiness and other anatomical features. No difficulty, however great, must be allowed to prevent the introduction, whenever possible, of exact quantitative methods in plant geography. Thus only will it advance beyond the vague and superficial descriptions of traveling plant geographers.

# SOME DYNAMIC STUDIES OF LONG ISLAND VEGETATION[1]

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Most studies of vegetation hitherto published consist largely of lists of species, with or without indications of relative abundance, morphological or other descriptive notes, illustrations, analyses of environmental factors, and speculations about succession; all of which tells what the vegetation *is* or attempts to explain why it is. It is also important to take a pragmatic view of vegetation and investigate what it *is doing*, just as a man should be judged not altogether by his appearance, ancestry, wealth or position, but also by the good he does. In other words, we should try to ascertain how much growth a given type of vegetation makes in a year, and how much food and water it takes from the soil; matters which ought to be pretty closely correlated with environmental factors.

To determine the annual increment of woody plants is not an easy matter, but many foresters have done it for restricted areas of forest (and usually for only one species at a time) by means of careful measurements and calculations. The measurement of the growth of herbaceous vegetation is much simpler, but strange to say very little has been done along that line, except for cultivated crops, or with an economic object in view. There is practically nothing on the subject in the latest botanical text-books and vegetation monographs, but it seems that a little work of the kind was done in Europe about thirty-five years ago.[2] The earliest American investigation of the dynamics of natural herbaceous vegetation that has come to the writer's notice is by Dr. David Griffiths in Bulletin 4 of the United States Bureau of Plant Industry (1901), on Range improvement in Arizona, in which he published some measurements of the yield of *Plantago fastigiata* near Tucson. In Bulletin 67 of the same series, by the same author (1904), the investigations were extended to a variety of herbaceous vegetation on the Santa Rita Range Reserve, south of Tucson; and Bulletin 367 of the United States Department of Agriculture, by E. O. Wooton (1916), contains additional data from the same area. In 1909 Dr. H. L. Shantz measured the yield of two or three types of grassland in eastern Colorado,[3] and a little later Dr. A. B. Stout studied a wild hay meadow or grassy peat bog near Madison, Wisconsin, in a similar manner.[4] A recent European study along this line is by Miss Marietta Pallis in an examination of the marsh vegetation in the delta of the Danube.[5]

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[1] Read at a meeting of the Ecological Society of America, December 27, 1916; and subsequently elaborated a little.

[2] See C. Schröter, in Actes du IIIme Congres International de Botanique (Bruxelles 1910), **2**: 117–118. 1912.

Herbs which do not have evergreen leaves obviously renew all their aerial parts and some of their subterranean parts every year. Consequently if one cuts a measured area of prairie or marsh vegetation at the surface of the ground at the end of the growing season he will have the results of a year's activity, minus some of the roots, and whatever foliage may have fallen and decayed during the summer. The loss from decay of spring annuals, early deciduous leaves, etc., can be largely avoided by making two or more cuttings from the same spot a few weeks apart. In marshes, however, there seems to be little loss of that kind, and a single cutting late in the season ought to give pretty accurate results.

The vegetation can be weighed both at the time of cutting and after it is thoroughly dry, and then burned to determine the amount of mineral matter taken from the soil in a year. An analysis of the ash should throw some interesting light on the composition of the soil and the availability of its several constituents.

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[3] Bull. U. S. Bur. Plant Industry, 201: 81. March, 1911.

[4] Trans. Wis. Acad. Sci., **17**: 405–469, *pl. 18–23*. October 1912.

[5] Jour. Linn. Soc. (Bot.), **43**: 233–290, *pl. 11–25*. July, 1916.

One who studies vegetation in this way does not need to know the names of the plants, nor to worry about the pernicious activities of species-splitters and name-jugglers, which have filled hundreds of pages of botanical magazines (but have been consistently excluded from The Plant World through all its changes of form and management). Of course there are several sources of error to be guarded against, such as personal inadvertences, errors of sampling, and variations of growth in different years according to the weather, but some of these tend to counterbalance each other, and others can be reduced to a minimum by making numerous determinations in different spots and in different years and averaging them.

During the season of 1916 the writer made measurements of a few easily accessible types of herbaceous vegetation in the western part of Long Island, by way of experiment. In most cases only one sample was taken, and that may not exactly represent average conditions, but of course one does not usually attain perfection in the first attempt. One square yard was the unit of area selected, but the results are expressed in pounds per acre, in order to facilitate comparson with similar studies already published. (Readers who prefer metric units can easily convert them.)

Each square yard of vegetation was weighed as soon as possible after cutting, and then allowed to dry for a month or more, with frequent exposures to the sun (and with the assistance of some artificial heat for some of the later ones), and weighed again. A state of absolute dryness of course would be better, but is not so easily attained. Determining the ash involved some minor difficulties, for the organic matter in hay will not burn up completely of itself, but requires the application of some external heat; and suitable incinerating apparatus is not to be found in most homes or even in botanical laboratories. Small amounts of ash were probably lost in the improvised apparatus used, but that does not materially affect the comparison between different samples.

The vegetation types studied are as follows:

1. Upland meadow or weedy grass-land among dwellings, College Point. The soil is described as "Miami stony loam" in the government soil survey of western Long Island (1905), and it is above the average in fertility, and differs from the soils at the other localities named below in being well supplied with earthworms. A few centuries ago it was doubtless covered with deciduous forest, examples of which can still be seen a few miles away. It was probably cultivated during part of the last century, and abandoned by farmers when residences became too numerous in the vicinity. The present vegetation is of a type very common in and around New York City, consisting mostly of European weeds, such as *Anthoxanthum*, *Dactylis*, *Plantago lanceolata* and *Trifolium pratense*. Two square yards about 50 feet apart, one partly shaded and one more exposed, were cut over twice, first on June 29 and next on September 9. The foliage that withered away before the first cutting and that which grew up after the last would add perhaps 10% to the total bulk.

2. A pure stand of *Spartina patens* in a brackish marsh between College Point and Whitestone (fig. 1). One cutting was made on September 13, which probably represents at least 95% of the year's growth, exclusive of roots.

3. *Typha latifolia*, with about 1% of other vegetation, near the same place, cut on the same date. A stand of average density, about 5 feet tall, with 30 stems (two or three of them fruiting) per square yard. When the spot was re-visited about a month later no subsequent growth could be detected.

4. *Phragmites communis*, a large patch in full bloom in same marsh, about 10 feet tall, with 77 stems per square yard or 372,680 per acre (fig. 2). Cut September 19, practically at the end of the season's growth. Quite a number of leaves had already fallen, but those were gathered up as completely as possible and weighed with the rest.

5. *Typha angustifolia* in a fresh marsh at head of same brackish marsh, 9 feet tall, with 61 stems per square yard, all sterile. Cut September 19. If there had been any fruiting stems the dry weight and ash would probably have been greater.

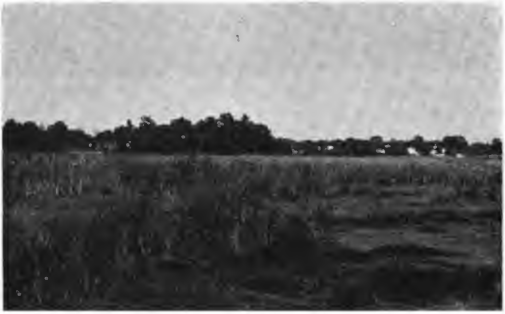

Fig. 1. Brackish marsh between College Point and Whitestone, with *Spartina patens* and *Panicum virgatum* in foreground and *Typha latifolia* in middle distance. September 9, 1916. Samples 2 and 3 were taken here a few days later.

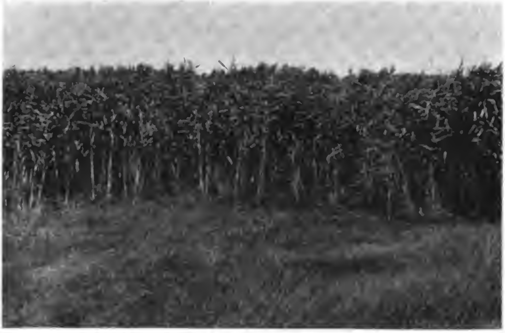

Fig. 2. *Phragmites communis* (in bloom), with *Spartina patens* in foreground. September 19, 1916. Sample 4 was taken here.

7. Hempstead Plains,[6] about 3 miles S.S.E. of Westbury. Vegetation mostly *Andropogon scoparius,* with some *Ionactis linariifolius* and a few other plants, somewhat sparser than the average for this area. October 3.

7. Hempstead Plains, about a mile S.S.E. of Westbury. Vegetation denser than the average, nearly all *Andropogon scoparius,* with culms about 3 feet tall. October 27.

The following table gives the results of the weighings, in pounds per acre:

| TYPE | FRESH | DRY | ASH |
|---|---|---|---|
| 1. Upland meadow | 16,940 | 4,350 | 495 |
| 2. Spartina patens | 16,940 | 8,848 | 279 |
| 3. Typha latifolia | 31,460 | 12,100 | 296 |
| 4. Phragmites | 48,400 | 24,000 | 1,585 |
| 5. Typha angustifolia | 53,240 | 15,443 | 843 |
| 6. Hempstead Plains | 4,538 | 2,420 | 168 |
| 7. Hempstead Plains | 8,220 | 5,975 | 265 |

Probably little significance is to be attached to the weights of the fresh vegetation, especially in the last two, which were cut in October and had evidently lost some of their water before that time. With these exceptions the one showing the highest ratio of dry to green weight is no. 2, which is a tough dense grass, and lost less than half its weight in drying. No. 4 is nearly equal to it in than respect, however.

In dry weight the *Phragmites* leads by a large margin. It would be interesting to know if there is any natural vegetation in the world that makes a greater growth per unit area in one season. The same species is very widely distributed, and one might suppose that in a warmer climate it would do still better. A photograph of a nearly pure stand of it at the edge of the Everglades was published in the Third Annual Report of the Florida Geological Survey (fig. 28, p. 286), and that is much more open. But the comparison is not quite fair, for that photograph was taken in April. The saw-grass which covers most of the Everglades makes a pretty dense growth, but as it is evergreen the foliage present at any one time represents more than one year's work.

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[6] See Torreys, **12**: 277–287. 1912.

The delta vegetation in Dobrudja studied by Miss Pallis contained quite a number of the same species found in the fresh and brackish marshes near College Point and elsewhere along our Atlantic coast, as well as some others not quite identical with ours but closely related. The most prominent plant there was a variety of *Phragmites communis*, represented by two forms differing in age; a stout juvenile form sometimes 17 feet tall, with 12 to 14 stems per square yard, and a slender adult form with about 90 to 130 stems per square yard. Miss Pallis weighed these in the fresh state only, and found both forms yielding about 14,500 to 19,400 pounds per acre of aerial parts and about the same of rhizomes.

Dr. Stout's Wisconsin bog vegetation, which contained many of the same species that occur in fresh marshes on Long Island, was cut the second half of August, and the yield of air-dry hay per acre ranged from 3430 pounds where the vegetation was about three-fourths *Carex stricta* to 7078 pounds where *Calamagrostis Canadensis* was the most abundant plant. These figures are somewhat below most of mine, but perhaps only because his hay was cut earlier in the season.

Dr. Griffiths, in the papers cited, found the annual growth of *Plantago fastigiata* in southern Arizona to be from 16 to 2466 pounds (dry) per acre, and of miscellaneous herbaceous vegetation from 15 to 1529 pounds, with an average of 270 pounds in spring and 799 in summer, or 1069 for the whole growing season. Professor Wooton arrived at very nearly the same average in the same region.

Dr. Shantz's Colorado hay was cut on August 23, 1909, and the yield per acre on "short grass" land was only 116 to 240 pounds per acre, while that on bunch-grass (*Andropogon scoparius*) land was 840 pounds. The bunch-grass land is very similar in aspect to the Hempstead Plains of Long Island, and has the same dominant grass. The soil is doubtless more fertile than most of that on Long Island, but the deficient rainfall in Colorado probably accounts for the low yield of hay, as is the case also in Arizona.

It is interesting to note that according to the old inhabitants the vegetation of the Hempstead Plains used to grow taller than it does now. If some one had only thought of measuring the yield of hay from the Plains fifty or a hundred years ago and placing the results on record we could now tell approximately how fast the apparent retrograde succession is progressing, if at all.

This investigation of marsh vegetation throws some light on a question raised some months ago[7], namely, whether or not the rate of growth increases with the progress of succession. In the brackish marsh near College Point *Phragmites* is much more abundant now than formerly, according to Mr. Edward N. E. Klein, a botanist and pharmacist who has always lived there (and to whom I am indebted also for considerable assistance in weighing and burning the vegetation samples), presumably on account of some of the salt water having been excluded by a tide gate. Where a patch of it adjoins one of *Spartina patens*, as in figure 2, the outposts of the *Phragmites* look like trees on the edge of a forest invading a prairie, on a small scale. The great difference in the bulk of the two plants per unit area, and especially in the amount of mineral matter taken from the soil, is brought out in the foregoing table. But as this is not a genuine case of natural succession it may not be safe to deduce any general principles from it.

In most of the cases above mentioned the yield of dry vegetable tissue is less than that produced by the average cultivated crop in average soils, even without fertilization; and the most likely explanation is that plowing, by aerating the soil, makes the plant food available more rapidly that it is under natural conditions.

None of the previous investigators cited seem to have made any attempt to determine the inorganic matter in their hay, which is probably as important as the dry weight, if not more so, for it indicates just what the vegetation is taking from the soil. (Of course in a state of nature most of it soon gets back into the soil to be used over again, but a not inconsiderable portion must be dissolved in rain-water, especially where the vegetation is subject to fire, and carried off into streams.) In my samples the ash percentages ranged from less than 3 in *Typha latifolia* to over 11 in the upland meadow, which occupies the most fertile soil and makes the best hay. The ash of my *Phragmites* and *Typha angustifolia* weighed more than the entire hay in some of the western localities.

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[7] Torreya, **16**: 139. June, 1916.

The ash samples themselves present some interesting differences. Those of *Spartina* and *Typha latifolia* after the final burning consist largely of hard porous lumps strongly resembling the slag from an iron furnace, and perhaps containing considerable iron and phosphorus, like the slag, as well as sodium from the salt water. That of *Typha angustifolia* is gritty, something like old plaster, while the remainder are fine gray powder like ordinary wood ashes, probably consisting largely of potassium carbonate. An analysis of these ash samples has not yet been possible, but it would doubtless give some interesting results.

These few examples, while perhaps of little value in themselves, may serve to point the way to an interesting and almost untrodden field of investigation. Similar studies of herbaceous vegetation should be made in other parts of the world by those who have the opportunity and the necessary enthusiasm. The method might be extended to shrubby vegetation, like the heaths of the North, the scrub of Florida, and the chaparral of California, by cutting clean an area of a few square yards without disturbing the roots, and then weighing the new growth on a part of it a year or two later. It will probably be found that similar combinations of soil and climate will in the long run produce about the same amount of vegetation per unit area per annum, whether it is herbs, shrubs or trees.[8]

[8] It may not be generally known to botanists that the reports of the last few United States censuses give the acreage and tonnage of "wild, salt or prairie grasses," cut for hay in each state and county, from which one can get an idea of the extent of prairie, meadow, or marsh, and the rate of growth of the vegetation in different regions. The average yield of such hay is about a ton to the acre, and the maximum about 3 tons; but the figures should not be taken too literally.

## BOOKS AND CURRENT LITERATURE

Plant Succession.—Clements[1] has devoted many years to the subject of the recognition, classification, and development of vegetation types, especially in the central and western portions of the United States. The book under review is based on field work and is an elaboration of the ideas already published in his paper on "Development and Structure of Vegetation" (Report of the Botanical Survey of Nebraska, No. 7, 1904). In it the author carries even further his analogy between the development of the vegetation and the development of the individual plant. He also applies the ecological method to the study of paleobotany. The system of classification here proposed, while based to some extent on the work of ecologists and plant geographers, is in its application almost entirely new. The analogy between the life history of a formation and the life history of an individual plant is the basis of the present book, for the succession within the formation and the development of the individual plant are regarded as analogous.

This book is an extended rather than a concise statement of the subject of plant succession. Into it is brought an immense amount of material from the related sciences, physiography, geology and meteorology. One who knows little of the subject will be confused by the mass of detail and by the introduction of a large number of new technical terms. Ecologists, foresters and other students of vegetation will find a critical reading most stimulating. Almost every paragraph suggests unsolved problems, although it is not always clear from the text which problems are still unsolved. To students of vegetation it represents a decided advance over the author's earlier works. Climax and development units are brought into a single system, of which the proposed terminology is complex enough to force difficult decisions, if not years of investigation, to determine the status of the community and the proper term to be applied.

The discussion of the effect of the plant community on the physical condition of the habitat is somewhat general and some of the conclusions should form the basis of instrumental study. This is especially true of those paragraphs dealing with water relations. Very few studies have been made which in any adequate way touch the moisture problem. The soil sampling systems employed are not extensive enough to afford more than superficial indications of the real moisture conditions under which plants grow. The moisture consumption of native plants is unknown and often the measurements recorded give no indication of the total amount of water available for growth. It is true the vegetation is in some ways the best indication of moisture conditions, but to interpret soil moisture conditions on the basis of vegetation and the vegetation on the basis of the inferred moisture conditions is a decidedly observational method. Moisture conditions cannot be studied without an equipment and amount of labor seldom supplied, but they are none the less essential to an interpretation of vegetation. A careful perusal of this portion of the book should suggest at once a score of unsolved problems, many of which are of profound importance in the study of vegetation.

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[1] Clements, F. E. Plant Succession: An Analysis of the Development of Vegetation. Pp. xiii + 512; pls. 61. Carnegie Inst. Wash. Pubn. 242, 1916.

Under stabilization and climax, the author emphasizes the conclusion that progressive invasion typical of succession everywhere results in stabilization. Stabilization is an increase in dominance and culminates in a climax. Both climax and development units of vegetation are considered and a system of classification proposed. In the brief historical summary the terms "formation" and "association" are discussed but the concepts involved by different authors in the use of these terms are not considered as seriously as could be desired. In the early stages of the development of any science the same terms may be used to signify now one thing and now another. Concepts are more important than terms and in the discussion of the association it is more important that the vegetation unit involved in the discussion be considered than that the term which was applied to this unit conform to present day usage.

The author has swung largely from the habitat basis to the development basis in this book, but the development basis is founded clearly on floristics and habitat. By using development it is possible to include in the formation distinctive outstanding communities such as grass and forest communities. Still the habitat is really the basis of the formation, although the climate is indicated by the vegetation. Up to the present the vegetation cannot be predicated from climatic data with the desired degree of certainty.

Clements defines a plant formation as follows: "The unit of vegetation, the climax formation, is an organic entity. As an organism, the formation arises, grows, matures, and dies. Its response to the habitat is shown in processes or functions and in structures which are the record as well as the result of these functions. Furthermore, each climax formation is able to reproduce itself, repeating with essential fidelity the stages of its development. The life-history of a formation is a complex but definite process, comparable in its chief features with the life-history of an individual plant. The climax formation is the adult organism, the fully developed community, of which all initial and medial stages are but stages of development. Succession is the process of the reproduction of a formation, and this reproductive process can no more fail to terminate in the adult form in vegetation than it can in the case of the individual plant."

He then proposed the following divisions of the plant formation—The association is the climax unit of the formation and is characterized usually by a mixture of two or more species. The same formation may have several climax units or associations. The association is made up of consociations which are the units of the association and are characterized by a single dominant species. The society is a minor group characterized by a subdominant species which may be prominent within an area marked by the consociation or the association. The society is a localized or recurrent dominant within a dominance. These societies may be aspect societies or layer societies. The clan is composed of secondary species and ranks below the society, although it is not necessarily a subdivision of it. In this classification the formation corresponds roughly to the subformation of the Swiss botanists, while the formation of the English botanists conforms more nearly to one of the development units since it is limited to the types of vegetation which develop on any particular soil type. In the plant association as defined by Clements three or more conditions can be recognized: i. e., the association proper, where the dominant species are mixed, and the areas where a single species is segregated and becomes dominant. The difficulty in application lies in the fact that the unit recognized in the field, to which the term "association" has been quite generally applied, will under this system become a consociation. The older term "association" will be applied to the mixed area which usually lies between the consociations; as, for example, pure forests of yellow pine represent a consociation, pure forests of Douglas fir a consociation, and the mixed area between an association. The association is also employed in a broader sense to include the two consociations and the mixed area.

Each of the above named plant communities is a climax and represents, according to the author, a final stage of development. Similar manifestations may be found which represent only earlier stages in the development. For these the author has proposed a similar set of terms. For the stage which will develop into an association he proposes the term "associes;" for the consociation, "consocies;" and for the society the term "socies;" and for the clan the term "colony;" and for the plants which develop from a single parent the term "family." The term "plant community" is now used by ecologists in a general sense to apply to any unit of vegetation.

The careful application of these terms will undoubtedly bring out many conclusions with respect to vegetation which would not otherwise be recorded, and to this extent they will greatly further the subject by forcing concrete expression of conclusions. They do not, however, insure the correctness of the conclusion. The distinction between a society and a socies is debatable and difficult to draw; still an attempt to make the distinction should lead to clearer thinking. Nor can the the reviewer escape the feeling that the association as here distinguished from the consociation does not clearly meet the conditions as found in nature and that while it may be a most convenient means of reducing the conditions of seeming chaos to a condition of order, a certain amount of forcing is necessary. This feeling is strengthened by the fact that conditions of soil and climate are more uniform over the large stretches of pure stands than in the mixed areas lying between. Clements refers to the *Artemesia-Sarcobatus* association as the climax association of the Great Basin, while Weaver (University of Nebraska Studies, Vol. XVII, No. 1: 1–133, 1917) later refers to an *Artemesia-Atriplex* association in the desert region of Washington. Both instances are attempts to force the vegetation into the system proposed by Clements. The conditions under which *Artemesia* grows are very distinct from those of either *Atriplex* or *Sarcobatus*. The plants are found growing together only in areas where conditions are changing rapidly or are locally very ununiform. Both cases represent comparatively narrow ecotones. It also seems unsafe to make the number of species involved a criterion of the plant association. It would seem more natural to find either a pure stand of one species as in the case of sage brush or yellow pine or a mixture of two to many species such as the grama-buffalo grass or *Andropogon* sod associations, of the Plains and Prairie.

More thorough study will undoubtedly enable future investigators to improve greatly the system here proposed. Still the application of this system, with a constant desire to test the conclusions which it forces, and not a slavish adherence to the plan will undoubtedly do much to clear up our present uncertain attitude toward the structure and development of the plant cover.

After a brief review the following terms are proposed for the successional series: A sere is a unit of succession leading to a plant formation. Where this process has been repeated several times on the same area the group is known as a cosere. (The cosere corresponds roughly with the English use of the term formation.) Clisere—a development leading to an adjustment with the climate. Eosere—the development during each geological era. Geosere is the development from the first creation of life on the earth to the present time and made up of the eoseres named to correspond to geological eras. A further division into pricere, a primary development; subsere, a secondary development; the hydrosere, a series originating in a water stage; and xerosere, originating in an arid habitat. The hydrosere is divided into the halosere, originating in salt water; and the oxysere, originating in water deficient in oxygen. The xerosere is divided into the lithosere, originating on rock; and the pasammosere, originating on sand. In this chapter is given the author's idea of the climaxes of the different seres or the plant formations. These climaxes are supposed to conform to climatic units.

The climax formations of North America are discussed and abstracts given of studies of successions which have been made within the various formation as well as those in Eurasia and other parts of the world. It becomes evident by a perusal of this chapter that up to the present time very little has been done in the application of exact ecological methods to the study of the causes of change in plant population.

Past climates and climaxes are disoussed from the basis of the paleobotanical literature. The author follows Saporta in distinguishing four vegetation periods—The Eophytic, the Paleophytic, Mesophytic, and Coenophytic. The works of Chamberlain and Salisbury, Humphreys, Huntington, and Schuchert are used to establish the author's conclusions. An extended review is given of changes of climate due to deformation cycles, to volcanic activity, and to variations in sunspots. Climatic cycles are discussed at length.

Succession during the Cenophytic era is termed the cenosere. The fossil remains of plants are interpreted by a method of inference based on the phylogenetic system. By the occurrence of certain genera it is inferred that the plant communities were of this or that well recognized ecological character. By this method it is rather clearly indicated that the advance of the ice sheet and the gradual change in the climate led to the changes from hardwoods to conifers, from conifers to shrubs, from shrubs to tundra, and from tundra to ice. This advance continued to the beginning of the reverse condition when ice gave way to tundra, tundra to shrub, shrub to conifer, and conifer to hardwood. Considerable attention is given to the successions in peat bogs, since here is found a comparatively complete record of past successions.

The Mesophytic and Paleophytic eras are treated in much the same way. The conclusions are reached largely by inference and seem fairly well substantiated by the study of fossil remains and geological structure.

The author has succeeded in bringing together into one volume an immense amount of information with respect to plant succession and has developed a system of nomenclature and classification far in advance of any heretofore employed. In putting the study of vegetation on a successional basis the author has avoided the difficulty previously experienced of having to deal with static and successional phenomena in separate systems. The present system is pliable enough to admit of the ready placing of vegetation types which are rapidly changing, and also of types which are relatively stable. Absolute climax types are doubtless nonexistent but the relative climax shown in many of our types of vegetation can be fitted into this system without misunderstanding. With this comprehensive discussion as a starting point, a study of succession, either primary or secondary, should be made in which each stage is fully analyzed and the physical conditions adequately measured with instrumental methods far more complete and thorough than any yet proposed, in which the causes of changes of type can be explained by accurately measured changes in the environment—a study combining physical methods and vegetation methods in which the instrumental data are actually presented to prove the changes which are indicated by the vegetation. In short, a real instrumental and vegetational analysis of a succession should be made, which will make clear the physical or chemical basis of each vegetational change. This must be done by a man on the ground and with the application of far more exact methods than those at present applied by plant ecologists. The exact methods of the physicist and chemist, the meteorologist and agronomist, must be brought to bear. Yet the problem is more than one of mere measurement. It involves a clear conception, but not a preconceived notion, of the ends to be attained by these measurements—such problems as aggressiveness or relative tenacity in maintaining a stand already established, the problem of competition, and the problems involved in establishment, the inter-action of vegetation on habitat, measured in physical, chemical and biological terms.

This book has marked out a course. The road along which the knowledge of vegetation is to advance must be built with a broad and secure foundation in published fact. It is hardly likely that this survey will be followed except in a general way, but it is the result of an immense amount of field work and ecologists should not fail to take every advantage of the information it affords.—H. L. SHANTZ.

MYCOLOGY AND PLANT PATHOLOGY.—The scope of this book[1] differs essentially from previous ones in that it recognizes as within its province the general field of mycology as well as the special field of plant pathology. The parts of the text fall under the headings: Mycology, General Plant Pathology, Special Plant Pathology and Laboratory Exercises in the Cultural Study of Fungi. The breadth of the work is indicated by the titles of the chapters, which include the morphology and classification of the various groups of pathogenic organisms, the causes and symptoms of disease, pathologic anatomy, galls, tree surgery and physiologic plant diseases. An appendix touches on fungicides, antisepsis and the culture of mushrooms, and gives keys for the determination of certain fungi.

It is obvious that the author set for himself a difficult task in treating so large a subject comprehensively within the limits of one small volume. To treat adequately either one of his major subjects, Mycology or Plant Pathology, in a single volume is sufficiently difficult. The reader must therefore be prepared to find certain phases of each of these subjects either omitted or but scantily touched upon. Still so skillfully has the author selected his subject matter and so concisely has he presented it that one is led to wonder at the amount of information given, rather than to note omissions. The adoption of the broadening subject of Mycology rather than Plant Pathology alone admits the consideration of many subjects closely related to Plant Pathology concerning which the pathologist should be informed, although they are not ordinarily given space in texts on pathology. This statement applies especially to Part I, Mycology, yet even here the dominant thought of pathology and the general presentation is made with pathology ever in mind, and the illustrations are in so far as possible drawn from pathogens. The chapters on General Plant Pathology are exceptionally valuable from their broad view point. In Special Plant Pathology the chapter listing specific diseases is long (64 pp.) and is essentially no more than a list, which being available elsewhere might have been omitted without real loss. The "detailed account of specific diseases" is good, concise, clear and reasonably comprehensive, though in many instances important diseases are left without discussion, e. g., only two diseases, rust and smut are considered on oats, one only on sweet potato, and one on tobacco. The laboratory exercises are helpful, but are largely those of general botany or bacteriology rather than of plant pathology and here especially is the author burdened by the breadth of his subject in the attempt to give the technique of micrometry, staining, preparation of culture media, etc., microtome sectioning, photography, the terminology of descriptive bacteriology, etc., etc. These directions in many instances will be found inadequate and had best be learned by the student from several separate books. Yet even here there is much that is valuable for reference. Particularly useful is the list of media, with directions for making them, including several not readily accessible in all laboratories.

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[1] Harshberger, John W. A Text-book of Mycology and Plant Pathology. Pp. xiii + 779; figs. 271. P. Blakiston's Son and Company, Philadelphia, 1917 ($3.00).

This book is well illustrated, the figures being in the main good. The diagrams are especially valuable. Very rich bibliographies accompany the text. Mechanically, typographically and rhetorically the book is commendable, though a few minor lapses in accuracy occur; on p. 488, "Alterniose" is given for "Alternariose;" on p. 644, it is said that lettuce drop "may be inoculated by means of the sclerotia of fungus, or by the mycelium laid upon the surface of scarified areas of the leaf." Mature sclerotia will in reality germinate only by forming ascospores, the mycelium is very short-lived, and scarification of the leaf is not necessary; on p. 646, *Neocosmospara* is recognized as the ascigerous stage of the wilt of cotton, etc. This was disproved by both Higgins and Butler. The book is perhaps not quite so nearly up to date as might be wished, e. g., on p. 118, *Urophlyctis alfalfae* is recorded as of South America and Germany, *Spongospora subteranea* is not found in the index or special discussion, though it is listed on p. 457. Citrus canker is not even listed for the orange.

Taken all in all it may fairly be said that the author has in one volume given much concerning Mycology and Plant Pathology, Bacteriological and Botanical methods. While as a text book on any one of these subjects it may be found either inadequate or overloaded, or both, it certainly will be an indispensable reference book for all teachers who have to do with either one of these subjects.—F. L. Stevens.

# NOTES AND COMMENT

In 1913 the Legislature of the state of California provided a fund of $60,000 for the purchase of suitable lands as a site for the Graduate School of Tropical Agriculture and Citrus Experiment Station of the University of California, and also appropriated $100,000 for laboratory buildings and $25,000 for director's residence, barns and other minor buildings. A tract of 475 acres was selected in the heart of the orange growing region, 2½ miles east of Riverside, California. The buildings provided in the appropriation are now completed and are to be dedicated with appropriate ceremonies on March 27. The forenoon will be given up to addresses of general scientific interest by men of national reputation. The Dedication Exercises at the afternoon session will be presided over by Dean T. F. Hunt, of the College of Agriculture, Berkeley, Cal., and will include addresses by President Benjamin Ide Wheeler, of the University of California, Dr. H. J. Webber, Director of the Citrus Experiment Station, and His Excellency, William D. Stephens, Governor of California. An evening reception will be given by Director and Mrs. H. J. Webber at their residence.

Dr. N. L. Britton has prepared, with the aid of several collaborators, an illustrated Flora of Bermuda, which will appear this spring. The volume will contain descriptions and illustrations of all the wild flowering plants, ferns and mosses of these interesting and isolated islands, together with descriptions of the many kinds of cultivated plants in the attractive gardens and public places. Chapters are devoted to the lichens, fungi and seaweeds, to the botanical and horticultural bibliography of the colony, and to the various botanical collections that have been made there.

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# RAUNKIAER'S "LIFE FORMS," "LEAF-SIZE CLASSES," AND STATISTICAL METHODS

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AND

A. L. BAKKE
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### III. SUMMARY OF THE VALENCE METHOD[3]

1. The valence method offers an objective means of investigating a plant formation by differentiating its species according to their frequency expressed numerically so as to serve both as a means of direct comparison of closely related formations and also as a basis for an indirect comparison by passing from systematic units (species) to units of another sort; viz., ecological or physiognomical, and thus permitting an exact comparison between formations which are floristically entirely different from one another.

2. For the ecological characterization of a formation the frequency of the occurrence and the growth habits of a species are the outstanding things, while physiognomical characterization is essentially dependent upon the aspect (mass condition) of the vegetation as a whole (in connection with frequency).

#### *A. Frequency*[4]

3. Frequency is determined by taking a number of sample areas of a certain size and expressing numerically, in terms of percent, the number of these samples in which the species in question occurs: Frequency percentage (F%).

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[3] Raunkiaer, C., Om Valensmetoden. Bot. Tids. **34**: 304-311. 1917.

[4] Raunkiaer, C., Measuring apparatus for statistical investigations of plant formations. Bot. Tidsskr. **33**: 45-48. 1912.

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MARCH, 1918

4. The necessary number of samples is attained as soon as the result becomes practically unchanged however much the number of samples is increased. How quickly this equilibrium is reached will be determined by the size of the samples—the smaller the samples the larger the number required but the more detailed will be the analysis.

5. In practice the size of the sample is determined by the proportional adjustment of the time consumed to the accuracy of the results required. As the result of my experiments I have found that 0.1 sq. m. is a suitable size, giving fairly constant results from a moderate number of trials (25 to 50).

6. If we investigate a formation which is essentially uniform, with ill-defined limitations, the samples may be taken either at random or along definitely determined lines. If we are not sure that the vegetation of a formation is essentially uniform, the question must be investigated, but it so happens that its investigation is similar to that of frequency determinations because the samples are, in this instance, taken in definite areas along marked lines and each sample is referred to a prescribed place in a hypothetical scheme. By this means the presence of a community differing from the one under investigation is at once detected by different frequency indices for the species or by the appearance of new species with higher frequency indices.

When a vegetation comprising several formations is under investigation, the samples must be properly distributed over the entire area according to the established boundaries if accurate results are to be obtained.

7. The sample-plots are selected and marked out most easily by using a metal ring fixed upon a walking stick holding a metal rod at right angles to the stick. This rod is of just such length that the outer end will describe a circle of 0.1 sq. m. when the walking stick is stuck into the soil.

8. In the analysis of the sample areas species are counted which have rooted living shoots within the area and also those which have perennial shoots above it, even if they are not rooted in the circle.

### *B. Ecological character (growth-form).*

9. Ecological character is expressed partly by descriptive terms and partly by statistical results, as the single adjustment (life-form) valence in a formation is shown by the frequency index as a medium between systematic (species) and ecological units (growth-forms). In this way biological formation spectra may be constructed not only for the "life-forms" (showing the adjustment of the species to survive the rigorous season) but also for other biological characters such as xeromorphism (leaf-size, leaf anatomy, etc.), pollination, and dispersal.

### *C. Height and mass*

10. The height of the individual species and the mass of the vegetation are two distinct factors in the physiognomy of a formation. As far as chamaephytes and phanerophytes are concerned the height is pretty completely expressed in the designation of the life-form (nanophanerophytes, microphanerophytes, etc.), and in investigating a formation of herbaceous plants the height may be determined directly. On the other hand, it is difficult to obtain an exact computation of the mass, for it is impossible in practice to determine its weight or volume, besides, such determinations would scarcely characterize the physiognomy. Hence we must content ourselves with computations of mass based upon estimates following inspection combined with the valence method determinations. One important feature of the physiognomy of the mass is the proportion of the area covered by the individual species.

11. The area covered is determined by perpendicular projection upon the substratum and is expressed as the surface per cent of the area in question. Areal percentage (see Lagerberg[5]), A%.

12. The size of the sample plots to be used in determining the areal percent (A%) is a matter of no theoretical significance but of very decided practical importance, the most practical is the

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[5] Lagerberg, T., Markflorans analys pa objectiv grund. Skogsvardsföreningens Tidskrift, 1914.

best. It cannot be directly compared with frequency percent which is determined by means of various different sample plot and is a proportional relationship, while areal percent is an absolute determination. Here again it seems that samples of 0.1 sq. m. are preferable because it is desirable to determine frequency at the same time as extent of distribution.

13. Areal percent determinations include all species having living aerial organs inside the boundary whether they are rooted or have perennial shoots. If this is compared with the rules for frequency determination, it will be seen that the frequency percent determined from a number of plots in which the species really occurs does not necessarily coincide with the species' actual frequency percent and should therefore be represented in another way; *e.g.*, AF% (Areal frequency).

14. Areal percent is obtained by estimating the number of surface units covered within the limits of a single sample plot; for example 10: here the sample is known to be divided into 10 equal parts and these are examined in turn for the number of units covered by the given species. The sum of the observed areas covered gives the areal percent.

15. The samples are located and marked out with the assistance of the same apparatus that is used in the frequency determinations. This may be accomplished by using a ring upon a walking stick with two radial rods that mark off a sector (of the circular sample) of a size which gives the smallest distributional unit area we wish to examine.

16. In the usual study of a formation, the areal percent will be of no great significance because its value in interpreting the physiognomy is too small a return for the labor required and we must remain content with a descriptive analysis of the contribution to the physiognomy made by a species' frequency. When, however, in a definitely limited area the small yearly variations in the abundance of a species are to be compared, the areal percent calculations will be very significant.

*D. Formations change with characterization of habitat.*

20. Plant climate is characterized and defined with the assistance of the floristic biological spectrum based upon the life-forms system which is based upon the essential adjustment of plants to the factors of environment, namely, their ability to survive the rigorous season.

21. An essential side of the biological characterization of formations is the ecological formation-spectrum which, by means of the frequency index, is built upon the same life-form system as that by which plant climates are characterized.

22. While not of fundamental biological importance the life-form system gives as a secondary result the type of physiognomy which characterizes the landscape.

23. Formation spectra have therefore both biological and physiognomical significance; biologically they characterize the formations with the life-form which primarily *dominates;* they also characterize the formations with respect to the life-form which determines the aspect of physiognomy of the vegetation.

24. Using the life-form system the following classes of life-forms result:

| Class. I. Megaphanerophyte formations | Examples |
|---|---|
| A. Evergreen | |
| a. Broad-leaved (mega-microphyll) | Tallest tropical and subtropical rain forest. |
| b. Narrow-leaved (micro-leptophyll) | Needle-leaved forest. |
| B. Deciduous | Monsoon forest. Deciduous temperate forest. |
| Class II. Mesophanerophyte formation | |
| A. Evergreen | |
| a. Broad-leaved (mega-microphyll) | Medium tall (8–25m.) tropical and sub-tropical rain forest. |
| b. Narrow-leaved (micro-leptophyll) | Needle-leaved forest. |
| B. Deciduous | Monsoon forest. Temperate deciduous forest. |

| | |
|---|---|
| Class III. Microphanerophyte formation | |
| A. Evergreen | |
| a. Broad-leaved (mega-microphyll) | Pigmy forest in tropics and sub-tropics. |
| b. Narrow-leaved (micro-leptophyll) | Pigmy or low conifer forest. |
| B. Deciduous | Low forest in tropical, subtropical and temperate zones; tall scrub. |
| Class IV. Nanophanerophyte formation | |
| A. Evergreen | |
| a. Broad-leaved (mega-microphyll) | Scrub palm, certain forms of maqui |
| b. Narrow-leaved (micro-leptophyll) | Maqui |
| B. Deciduous | Low scrub. |
| Class V. Chamaephyte formation | Examples |
| A. Evergreen (subdivided on the basis of xeromorphy and leaf size) | Certain forms of heath. |
| B. Deciduous | Formations of chamaephytic species of *Salix*, *Vaccinum*, etc. |
| Class VI. Herbaceous formations (Hemicryptophytes, Geophytes and Therophytes). Subdivided first, and foremost according to height (tall perennials, low perennials) and xeromorphy | Hygrophilous and mesophilous meadow, forest floor formations, grass-steppes, etc. |
| VII. Helophyte formation | |
| A. Tall | Formations of *Typha*, *Scirpus lacuster*, *Phragmites*, etc. |
| B. Low | Formations of *Carices*, *Equisetum*, etc. |
| VIII. Hydrophyte formation | |
| A. Floating-leaved | |
| a. Rooted | Formations of *Nymphaceae*, *Potamogeton*, etc. |
| b. Free floating | Formations of *Hydrocharis*, *Lemna*, etc. |
| B. Submerged | |
| a. Rooted | Formations of *Potamogeton*, *Myriophyllum*, *Characeae*, etc. |
| b. Non-rooted | Formations of *Ceratophyllum*, *Utricularia*, *Lemna*, etc. |

The above is a system of formation analysis into primary divisions so fundamental that the biological and physiognomical coincide and are both emphasized. Within its limits there is a place for off-shoots or subdivisions of larger or smaller extent expressing characters of special biological significance which require special biological (ecological) characterization in the systematic analysis of a narrowly limited formation.

25. By more intensive studies of climatic factors, of soil chemistry, of physical and biological conditions and by a wide investigation of the morphological, anatomical and physiological nature of plant species, ecology will be able to reach an understanding of the place of each individual species in a formation.

# THE EVALUATION OF THE SOIL TEMPERATURE FACTOR IN ROOT GROWTH

W. A. CANNON

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When reduced to its lowest terms the information necessary for use in evaluating the temperature factor in the growth of roots includes in addition to the temperature itself, the rate of growth at different soil temperatures. With such data, and by employing the time factor, we are in position to calculate the *TR*[1] for any species. This in brief is the total expected root growth of the species, that is to say, the summation of root growth at the temperatures employed.

This method is of some interest from an ecological as well as from a physiological point of view. Where a species is restricted in its general distribution by unfavorable temperatures, it is probable that at such limits of distribution the value of *TR* would be relatively small, whereas at the center of the range it would be relatively large. It therefore seems possible, were sufficient data on hand for the purpose, to plot the *TR* as isolines. The broad effects of different soil temperatures on root growth, and the relation of the root-soil temperature response to the general distribution of the species could in this manner be clearly brought out.

This physiological method of temperature evaluation as a factor in root growth can be sufficiently illustrated by a single example. For this purpose reference can be made to the rates of root growth of *Covillea tridentata*, and these can be related to soil temperature at a depth of 30 cm. at two stations, namely, the Coastal Laboratory, and the Desert Laboratory, for the month of August, 1916. It will be recalled that *Covillea* is one of the most characteristic shrubs of the Tucson region. Up to this time, on the other hand, all attempts to grow it at the Coastal Laboratory have failed.

---

[1] Rate of hourly root growth for any species at any given soil temperature multiplied by the number of hours the soil was at that temperature.

*Hourly growth rate of roots of Covillea tridentata at different soil temperatures*

| | *mm.* |
|---|---|
| 15°C. | 0.1 |
| 20°C. | 0.2 |
| 25°C. | 0.4 |
| 30°C. | 0.5 |
| 32°C. | 1.6 |

In the above table is presented what may very likely be considered average rates of root growth at the soil temperatures given and as established by unpublished[2] experiments. If we consider any root we are aware that it represents responses to a range of temperature which may or may not be considerable, and, from the foregoing table of rates of growth at different soil temperatures, it is clear that the total growth is composed of units of different time values. It may better illustrate the difference in effectiveness of the different temperatures of the soil as factors in root growth if we imagine such a root to have been exposed to the five different soil temperatures given above, for example, but for an equal period of time to each. From the rates of growth the percentage increase for each temperature can be easily calculated. This would be as follows:

| | *per cent* |
|---|---|
| 15°C. | 0.035 |
| 20°C. | 0.071 |
| 25°C. | 0.14 |
| 30°C. | 0.178 |
| 32°C. | 0.57 |

Since 32°C. is about the optimum temperature for the growth of the roots of *Covillea* it is also the temperature of maximum effectiveness so far as root growth is concerned. Or, viewed from the standpoint of the plant, at a temperature of 32°C. it attains its maximum efficiency as to growth. The temperature of minimum efficiency, on the other hand, is about 15°C.

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[2] Preliminary notice in Yearbook, Carnegie Institute, Washington, No. 15, 1916.

The illustrations show, in brief, that, as related to *Covillea,* a soil temperature of 32°C. is over 16 times as effective as one of 15°C. It is interesting to note also that the effectiveness of temperature of 32°C. is over three times that of 30°C.

As further illustrating the advisability of considering separately representative degrees of temperature in studies where temperature forms a part, the *TR* for Carmel and Tucson for one month can be given. Below is presented the total number of hours during which the soil in August, 1916, at a depth of 30 cm., at Carmel and Tucson, was at the following temperatures, namely: 15°C., 20°C., 25°C., 30°C., and 32°C.

| | 150°C. | 20°cm. | 25°cm. | 30°cm. | 32°C. |
|---|---|---|---|---|---|
| | *hours* | | | *hours* | *hours* |
| Carmel | 744 | | | | |
| Tucson | | | | 547 | 197 |

By calculating the *TR* for each temperature we have the following results,—the expected root growths:

| | *mm.* |
|---|---|
| Carmel, 744 hours at 15°C., | 74.4 |
| Tucson, 547 hours at 30°C., | 273.5 |
| Tucson, 197 hours at 32°C., | 315.2 |

The *TR* for Carmel for August, therefore, is 74.4 while that at Tucson for the same time is 588.7.

It is very evident that the *TR* is so low for Carmel during the month of August that anything approaching a vigorous condition of the species is not to be expected for that month, and as a matter of fact the *TR* would be extremely small for all of the other months as well. Survival of the species at this station would hardly be expected. At Tucson, on the other hand, the *TR* is relatively large. It appears therefore that the soil temperatures at a depth of 30 cm. at Carmel, and with reference to *Covillea,* are not effective temperatures, whereas the soil temperatures at Tucson are effective. What constitute effective soil temperatures for any species must be a mooted question, but for practical purposes it may be considered to be such as induce sufficient root growth to bring about the establishment of the species. In this connection favorable moisture relations and favorable soil aeration are assumed.

It may emphasize the really great difference in the effectiveness of the temperature of the soil at Carmel and at Tucson, so far as the influence on root growth of *Covillea* is concerned, if we compare the *TR* of each to what might be expected if every hour of the month were at the optimum temperature and if the maximum rate of root growth were maintained throughout that period. Under such circumstances the root growth would be 1190 cm. It is thus seen that at Carmel in August the growth under actual conditions could not be over one-sixteenth the maximum at the optimal temperature, while that at Tucson would be approximately one-half the maximum. Therefore, if a numerical expression of the relative intensity of the effectiveness of temperature conditions at a depth of 30 cm. at the two stations is desirable, it can be said that the effectiveness of the soil temperatures at Tucson in August are approximately eight times that of the temperatures of the soil at the same depth and at the same time at Carmel.

# BOOKS AND CURRENT LITERATURE

The Ecology of Prairie and Woodland.—After a hiatus of eighteen years the activity of the Botanical Survey of Nebraska has been resumed under the direction of Raymond J. Pool, and the first of a new series of papers on the vegetation of the state has appeared. This is a study by J. E. Weaver and Albert F. Thiel of the conditions existing in the tension zone between prairie and woodland, and is based on work in both Minnesota and Nebraska.[1] Throughout the summer months weekly or fortnightly readings were taken of the moisture of the soil at 0 to 10 cm. and 10 to 30 cm., and measurements of the evaporation. These data were secured in parallel series for high prairie, low prairie, hazel thicket and oak forest, a series of communities progressing from xerophytic to mesophytic in the order named. The graphs displayed show that for several weeks the soil moisture in the high prairie falls below the amount required by plants, as indicated by the somewhat hypothetical wilting coefficient. In the hazel scrub the moisture falls for a briefer period to an amount somewhat below the requirements of plants. In the low prairie and oak forest the moisture remains well above the minimum requirement of plants. The evaporation graphs show that the readings for this condition are progressively lower as we pass from the more xerophytic to the more mesophytic communities. Measurements were made of the rates of transpiration of the prairie rose in the prairie and scrub conditions, and of oak seedlings in prairie, scrub, and forest conditions. These show that lower rates prevail in the more mesophytic conditions, the seedlings transpiring more than twice as much in the hazel scrub as in the forest, and over eight times as much in the prairie as in the forest.

The evidence presented by the authors leads them to the conclusion that the conditions of the high prairie are such as to make invasion by plants of the scrub dependent on a concurrence of favorable summers. The success that attends the planting of trees on the prairies has led the authors to an investigation of the fate of tree seedlings, which is still in progress.

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[1] Weaver, J. E., and Thiel, Albert F. Ecological studies in the tension zone between prairie and woodland. Bot. Surv. Neb. New Series No. 1, pp. 60, figs. 38. Lincoln, 1917.

This well executed and clear-cut investigation brings out strongly the manner in which the vegetation of each community in a tension region influences the environmental conditions and thereby promotes invasion by plants of a more mesophytic character. Since our knowledge of plant succession has been so widely extended and so thoroughly elaborated, it promises important results that we should now divert our attention from the successional relation which one community sustains to another and turn our efforts to an investigation of the relation of each successional stage to the physical conditions under which that stage holds sway.—FORREST SHREVE.

A NEW BIOLOGICAL TEXT.—This second edition of Professor Calkins Biology, somewhat enlarged and revised, is a most welcome addition to the existing list of elementary texts intended to present the general facts of Biological phenomena, and differs from most of the books of this class in that it focuses attention upon general principles and processes, rather than upon structures and types.[1]

The presentation of the subject matter is pleasing and orderly, beginning with a consideration of living and lifeless matter, which is well done in a brief space. The author then gives in order: the main facts and activities of protoplasm and the cell organization and its activities; organisms of one cell; organisms of tissues; plants the food of animals, and the source of animal energy; organs and organ systems; homology and the basis of classification; parasitism and physiological adaptation; the perpetuation of adaptations.

Throughout the text function occupies a conspicuous position, structures being considered only in relation to activities, and presented to a less degree than is usual in texts intended for elementary instruction.

The author, in a surprisingly brief space, has vividly protrayed the essential processes of living things, and deserves the thanks, and support of those who must teach to beginners the basic facts of biology.—WILLIAM L. TOWER.

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[1] Calkins, Gary N. Biology. Pp. v + 255, illustrated. New York, Henry Holt and Company, 1917.

# NOTES AND COMMENT

The Degree of Doctor of Philosophy was conferred upon sixty-five candidates who presented research theses in Botanical science to sixteen American universities in 1917. Nearly one-fourth of the total number were given by the University of Chicago. So far as can be determined by an inspection of the titles, the distribution into special subjects gives 23 to physiology, 11 to pathology, 7 each to morphology and ecology, 6 to bacteriology, 4 each to mycology and embryology, 2 each to taxonomy and genetics, and 1 to paleontology. The notable feature of this phase of the matter is the growing interest in physiology, nearly two-thirds of the theses indicating a physiological view-point. Some of the subjects in ecology might well be assigned directly to physiology also.

Notwithstanding the emphasis that has been laid upon genetics in research and in breeding operations during the last fifteen years, but few students appear to carry their work so far as to present a thesis. The conditions suggest that the demand for experienced workers is so great that they are called to take positions and responsibility in dealing with the subject-matter early in their careers.

### *Brown University*

Walter Chadwick Nelson. The gas-bacillus, *Bacterium welchii* Migula, in milk.

Marion Dodge Weston. Illustrated key to the fossil flora of the carboniferous period of the United States.

### *Columbia University*

Ralph Randles Stewart. A check list of the plants of Ladak (western Tibet) with a discussion of the flora.

### *Cornell University*

Charles Chupp. Studies on club root.

Walter H. Burkholder. Anthracnose disease of the raspberry and related plants.

Howard Bowman Ellenberger. Study of the bacterial growth in ice cream.

Royal Joyslin Haskell. *Fusarium* wilt of the potato in the Hudson River Valley, New York.

Laurence Howland MacDaniels. Histology of the phloem in certain woody angiosperms.

**Ephraim Laurence Palmer.** Study of American weeds with keys to their seeds and fruits.

**Doak Bain Carrick.** Resistance of roots of some fruit species to low temperatures.

**Eugene Peyton Deatrick.** Effect of manganese compounds on soils and plants.

**Gertrude Elizabeth Douglas.** Study of the development in the family Agaricaceae.

**David Stout Jennings.** Effect of certain colloidal substances upon the growth of wheat seedlings.

*George Washington University*

**Leonard Lee Harter.** The pod blight disease of the lima bean (*Phaseolus Lunatus*), caused by *Diaporthe Phaseolorum* C. & E.

**John William Roberts.** The source of apple bitter-rot in ections.

**Arthur William Sampson.** Climatic conditions as related to plant growth and other physiological activities.

*Harvard University*

**Sidney Fay Blake.** A revision of the genus *Viguiera.*

**Charles Drechsler.** Studies on the genus *Actinomyces,* with special reference to its development and morphology.

*Johns Hopkins University*

**Edward Elway Free.** The oxygen requirement of plant roots in relation to soil aeration.

**Frank Merrill Hildebrandt.** A physiological study of the climatic conditions of Maryland as measured by plant growth.

**Earl Steinford Johnston.** The seasonal march of climatic conditions in a greenhouse, as related to plant growth.

**William Edward Tottingham.** A preliminary study of the influence of chlorides upon the growth of certain cultivated plants.

**Sam Farlow Trelease.** The relation of salt proportions and concentration to the growth of young wheat plants in nutrient solutions containing a chloride.

*Indiana University*

**Mildred Nothnagel.** Fecundation and the formation of the primary endosperm nucleus in certain Liliaceae.

*University of California*

**Robert Clinton Rhodes.** Binary fission in *Collodictyon triciliatum* Carter.

**Selman Abraham Waksman.** Studies on proteolytic activities of soil microorganisms, with special reference to fungi.

*University of Chicago*

**Arthur Laurence Bakke.** Studies upon the determination of wilting by the use of standardized hygrometric paper.

**John Theodore Buchholz.** The suspensor and early embryo of *Pinus.*

HAROLD DUDLEY CLAYBERG. Physiographic ecology of Walloon Lake, Petoskey region.

WINFIELD SCOTT DUDGEON. The morphology of *Rumex crispus*.

ENRIQUE EDUARDO ECKER. The pathogenic effect and nature of a toxin produced by *B. Paratyphosus* bacillus.

WRIGHT AUSTIN GARDNER. The effect of light on the germination of seeds.

EZRA JACOB KRAUS. Vegetation and reproduction, with special reference to the tomato (physiological and horticultural aspects).

HENRY REIST KRAYBILL. Vegetation and reproduction, with special reference to the tomato (chemical aspects).

WILFRED WILLIAM ROBBINS. Successions of vegetation in Boulder Park, Colorado.

DEAN HUMBOLDT ROSE. Oxidase activity and chemical composition of healthy and diseased apple bark.

RIAL CATLIN ROSE. Conditions and microchemistry of germination of the seeds of *Tilia*, *Sambucus* and *Rubus*.

MANDAYAM A. SAMPATHKUMARAN. Stelar cambium and its derivatives.

HOMER CLEVELAND SAMPSON. Chemical changes accompanying abscission in *Coleus Blumei*.

WARREN GOOKIN WATERMAN. The development of root systems under dune conditions.

BERTRAM WHITTIER WELLS. A survey of the zoocecidia of northeastern United States and Eastern Canada.

### *University of Illinois*

HARRY WARREN ANDERSON. The yeast-like fungi of the human intestinal tract.

HENRY GRANGER KNIGHT. Acidity and acidimetry of soils.

NEWTON LYMAN PARTRIDGE. The effect of ventilation on apples in cold storage.

ELMER ROBERTS. Fluctuations in a Mendelian character and selection.

### *University of Michigan*

CLINTON ALBERT LUDWIG. The influence of illuminating gas and its constituents on certain bacteria and fungi.

### *University of Minnesota*

DONALD FOLSOM. The experimental modification of *Ranunculus* under control.

FRANCES LOUISE LONG. The quantitative determination of photo-synthate in relation to light in various species.

HARVEY STALLARD. Secondary successions in the climax formations in northern Minnesota.

WILLIAM DORNEY VALLEAU. A study of sterility in the strawberry.

### *University of Pennsylvania*

H. H. M. BOWMAN. Ecology and physiology of the red mangrove.

FRANKLIN B. CARROLL. Development of chasmagamous and cleistogamous flowers of *Impatiens fulva*.

*University of Wisconsin*

**Firman Edward Bear.** A correlation between bacterial activity and lime requirement of soils.

**Eubanks Carsner.** Studies upon the angular leaf spot disease of cucumber.

**Henry L. Fulmer.** Influence of carbonates of magnesium and calcium on bacteria of certain Wisconsin soils.

**Thomas Lawrence Hills.** The influence of nitrates on soil bacteria.

**Fred Reuel Jones.** A study of certain alfalfa and clover diseases.

**Robert Delafield Rands.** The early blight of potato and related plants.

**Wendell Holmes Tisdale.** 1. Relation of temperature to the growth and infecting power of *Fusarium lino*. 2. Flax wilt: a study of the nature and inheritance of wilt resistance.

*Washington University*

**S. M. Zeller.** Studies in the physiology of the Fungi II. *Lenzites saepiaria* Fries, with special reference to enzyme activity.

**G. W. Freiberg.** Studies in the mosaic diseases of plants.

*Yale University*

**Nathan Berman.** Studies on bacterial metabolism: the behavior of bacteria towards proteins and their cleavage products; the influence of carbohydrates on nitrogen metabolism.

**Laurence Vreeland Burton.** Correlation studies of gas-producing bacteria with special reference to members of the *Colon-Aerogenes* group found in soils.

**Edward Fred Woodcock.** Observations on the development and germination of the seed in certain Polygonaceae.

—D. T. MacDougal.

The War Emergency Board of the American Phytopathological Society, which was organized at the Pittsburgh meeting during the holidays, held a meeting in Washington, February 9 to 11. The organization of this board is the result of a determination on the part of plant pathologists to do their part in winning the war. Certain problems of nation-wide importance are being handled. At the special meeting reports on these projects were made. A census of all persons able to do pathological work is being taken and encouraging progress was noted. Other projects on fungicides and machinery, emergency research, plant disease survey, and crop loss estimates were considered at some length. Plant pathologists have in the war conditions a great opportunity for service to the commonwealth, for there is no more vital feature in maintaining maximum crop production than that of the reduction of leakage due to crop diseases. The board is working with all existing agencies of state and nation. The members of the board are H. H. Whetzel, Cornell University; F. D. Kern, The Pennsylvania State College; E. C. Stakman, University of Minnesota; H. P. Barss, Oregon Agricultural College; H. W. Barre, Clemson College; G. H. Coons, Michigan Agricultural College; and G. W. Lyman, U. S. Department of Agriculture.

A bulletin entitled Life Zone Investigations in Wyoming (North American Fauna No. 42) has been prepared by Mr. Merritt Cary. The same lines of treatment are followed that have already been made familiar by Mr. Cary's Biological Survey of Colorado, Mr. Bailey's Life Zones and Crop Zones of New Mexico and other publications of the Biological Survey. The life zones from Upper Sonoran to Arctic-Alpine are described and their characteristic species of plants and animals listed. A concluding section is devoted to notes on the distribution of conspicuous trees and shrubs. Wyoming lies wholly above an elevation of 4000 feet, about one-third of its area being in the Upper Sonoran Zone and about one-half in the Transition Zone. The latter zone is made to comprise regions dominated by grasses, by sage brush or by western yellow pine.

A revised and somewhat enlarged third edition of Russell's Soil Conditions and Plant Growth has been issued by Longmans, Green and Company ($2.00). The revisions are to be found throughout the book but have taken place chiefly in the chapters on the Composition of the Soil (designated Constitution of the Soil in the second edition) and on the Relationship between the Micro-organic Population of the Soil and the Growth of Plants. A new chapter has been added on Colloidal Properties of Soil, dealing with the absorption of salts by soils, the colloidal character of soil acidity, the formation of hard-pan, and the relation of colloids to soil evaporation and to the biochemical reactions taking place in the soil. The Selected Bibliography has been increased by about 25 per cent.

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# The Plant World

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# SOME FACTORS AFFECTING INULASE FORMATION IN ASPERGILLUS NIGER

V. H. YOUNG

*State University of Iowa, Iowa City, Iowa*

## A. INTRODUCTION

The purpose of the work herein described has been to investigate in a quantitative as well as qualitative way the formation of an enzyme in a living organism. For such a study certain saprophytic fungi are especially suited since environmental factors can be more definitely controlled with them than with other plants.

The work was done in the Laboratories of Plant Physiology of the University of Wisconsin and the author is indebted to Prof. J. B. Overton for facilities, aid and encouragement.

The work of Katz, Went, Knudson, Dox, Kylin, and others on the quantitative and qualitative regulation of enzymes in the fungi has served as a basis for the work and reference will constantly be made to certain phases of their work. It is proposed to study the effect of age and carbohydrate nutrition on the enzyme content of a fungus. The work has been confined almost entirely to the as yet little known enzyme "inulase," and practically all the investigations have been with *Aspergillus niger.*

## B. REVIEW OF LITERATURE

The early literature dealing with fungal enzymes as well as the more recent literature is so completely reviewed in the publications of the above mentioned authors that it has not been thought necessary to consider in detail any of the literature except that definitely germane to the subject of the investigation.

The presence of inulin in plants has been known formany years. Green (1888) was the first to isolate an enzyme which would hydrolyze inulin. He called the enzyme, which he ex-

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tracted from the tubers of *Helianthus tuberosus*, "inulase." He was able to demonstrate that the enzyme was not present in the dormant tubers in an active condition but rather in the form of its zymogen. Inulase has been very little studied from the point of view of the factors influencing its secretion although, as will be seen below, some work of a valuable nature along this line has been done.

### *a. Literature of enzyme regulation*

It is a definitely established fact that environmental factors are more or less efficient in stimulating or retarding the formation of enzymes in the fungi. In the literature this has been termed "quantitative" regulation of enzyme formation. Many have asserted that a change in environment does not cause a change in the kind of enzyme produced, while others have asserted that this is not the case. A change in the environment inhibiting the formation of an enzyme, which would otherwise be produced or a change initiating the formation of an enzyme not usually produced, is termed "qualitative" enzyme regulation. The study of enzyme regulation obviously centers around these two ideas. Various environmental factors might be considered as affecting enzyme formation: *e.g.*, temperature, light, moisture, the presence of oxygen, the presence of inorganic salts, and organic food substances. As a matter of fact the last of these factors, *i.e.*, organic food materials, has been the only one considered to any great extent, although some of the other factors mentioned have been studied.

Katz (1898) has studied the regulatory secretion of amylase in *Aspergillus niger*, *Penicillium glaucum*, and *Bacillus megatherium* and finds that the effect of various other substances serving together with starch as a source of carbon is in general to very greatly inhibit the secretion of amylase. Cane sugar, grape sugar, lactose, maltose, glycerin, quinic acid, and tartaric acid were used. The rate at which starch disappeared from the culture medium is taken generally as an index of amylase formation but in certain cases the enzyme content of the mycelium is determined. With *Penicillium glaucum*, Katz finds that the presence of starch alone in the culture medium stimulates the fungus to form large amounts of amylase. Small amounts of cane sugar or glucose (1.5 to 2%) largely inhibit the formation of amylase. Lactose in 10% solution retards the formation of amylase, but a 3% solution has no effect. The effect of maltose is somewhat similar. Katz shows that the action of amylase itself is not affected by the presence of sugar in the concentrations used.

The inhibitory effect of sugars on amylase formation in *Aspergillus niger* as described by Katz (1898) is much less marked than in *Pencillium glaucum* and even as large an amount as 30% does not entirely inhibit its formation. The inhibitory effect of maltose, erythro-dextrin, glycerin, tartaric acid and quinic acid decreases from first to last in the order named. He finds that *Aspergillus niger* on culture media with starch only grows very feebly and forms only a small amount of diastase, but that the addition of 1.5% of sucrose stimulates both the growth of the fungus and the amount of enzyme formed. Katz believes that the inhibitory effect of these substances on amylase formation is not in proportion to their mass but that the effect is purely stimulatory.

In the case of *Aspergillus glaucus* and *Penicillium glaucum* Duclaux (1899) concludes that there is a certain qualitative enzyme production, and that enzyme formation in *Penicillium glaucum* depends upon nutrition. He, however, investigated only those enzymes which were secreted into the culture medium, taking no account of the enzyme content of the fungi themselves, which cannot be considered as a sufficient criterion.

Herissey (1899) in a thesis entitled "Recherches sur l'Emulsine," among other problems has studied the conditions, leading to the appearance of emulsion in *Aspergillus niger*, and finds that cultures grown on Raulin's solution for twenty-three to twenty-five hours give no indication of the presence of emulsin, but, when left for forty-eight hours, a vigorous emulsin is obtained. If *Aspergillus* is grown on Raulin's solution containing three to four times as much ammonium nitrate as usual, and the amount of ammonium nitrate used is replaced at the end of every twenty-four hours such cultures grow for a month without sporulating and at the same time yield no enzyme capable of hydrolyzing amygdalin. Such cultures when "starved" on distilled water produce a large amount of emulsin within forty-eight hours. It thus appears that emulsin is produced when sugar is the source of carbon, even though no glucoside is present and that ammonium nitrate in large amounts inhibits emulsin formation. Emulsin appears to be formed as the result of starvation.

Went (1901), in a voluminous article on the influence of nutrition upon the formation of enzymes in *Monilia sitophila*, finds that at least ten enzymes are formed by this fungus as follows: viz., maltoglucase, trehalase, raffinase, invertase, cytase, amylase, lipase, tyrosinase, trypsin and rennetase. All of these enzymes with the exception of trehalase are secreted into the culture medium and may be precipitated from it with alcohol, although they suffer some loss of activity in this process. According to the conditions under which they are formed, Went separates these enzymes into three groups: (a) those that are found in at least small quantities when the fungus is grown on any medium, (b) those that are formed only when certain substances chemically allied to their substratum are present, and (c) those that are formed only when the particular substrate on which they act is present in the culture medium. Enzymes belonging to the first named class are tyrosinase, amylase and invertase. Trypsins and rennetase belong to the third class. The formation of rennetase is entirely dependent on the presence of casein in the culture medium. Maltase is formed only when carbohydrates are present and in addition a nitrogen-containing salt. Proteins are in some cases able to stimulate the secretion of the carbohydrate-splitting enzymes and Went suggests that this may be due to the presence of the carbohydrate molecule in them. When a substance causes the secretion of an enzyme the increase of this substance into the culture medium causes an increase in the secretion of that enzyme. Thus solutions up to 10% of dextrin, 5 to 10% of maltose, or 10% of raffinose cause an increase of enzyme secretion. The author says that this increase in secretion is not due to the increase in osmotic pressure but does not explain the reasons for his belief. Trehalase is formed when culture media containing trehalose are used but it does not diffuse out into the culture media; the glucose formed by it, however, does diffuse out and may be detected by appropriate means. Invertase is formed when the culture medium contains sucrose, glucose, maltose, glycerin, acetic acid, lactic acid, malic acid or peptone. When glycerin is present in the culture medium, starch is transformed to glucose as in the usual case, but in the process no maltase is formed, as is shown by the fact that maltose added to the culture medium remains unchanged. Went concludes that in general the secretion of enzymes is not to be considered a hunger phenomenon, as so many workers contend, since there is generally more enzyme secretion in those fungi which are well nourished.

The excellent work of Dox (1910) on the enzymes of *Penicillium* and *Aspergillus* includes much work of a truly physiological character. He studied principally *Penicillium camemberti* growing cultures of the fungus on both Raulin's and Czapek's media. These media were found not to cause a hydrolysis of the carbohydrates of the culture medium, a result which no doubt has affected the results obtained by many other workers. Cultures were grown at laboratory temperature in Erlenmeyer flasks. Dox employs the "acetonedaurhefe" method of Albert and Buchner for the preparation of his enzyme powder and considers only the enzymes of the mycelium at the time of its sporulation.

Dox finds that nucleic acid is decomposed by enzyme preparations from *Penicillium camemberti* "irrespective of the presence of nucleic acid in the culture medium." These results differ from those of Iwanoff (1903), who finds that the formation of nuclease is dependent on the presence of nucleic acid in the culture medium and that no nuclease is formed on a medium containing only inorganic salts and carbohydrates.

*Penicillium camemberti* was found by Dox to have the power of hydrolyzing fat under proper conditions, but it was not determined whether or not the presence of fats in the culture medium causes an increase in the amount of lipase formed. Cultures grown on sucrose were found to have a very feeble lipolytic activity. Emulsin capable of hydrolyzing amygdalin, arbutin, salicin, and phlorhizin is formed when sucrose is used as a source of carbon.

Dox also has carried out a series of experiments on the effect of various carbohydrates on the formation of enzymes which hydrolyze them, and finds that cultures of *Penicillium camemberti* grown with sucrose as a source of carbon yield very small amounts of amylase. Enzyme preparations from cultures of the fungus grown on sucrose, maltose, lactose, glucose, starch and inulin all show some amylolytic activity, but that obtained from cultures grown on maltose and more especially on starch show the greatest amylolytic activity.

Very interesting results were obtained by Dox in a study of the inulase of the same fungus. The effects of sucrose, maltose, lactose, starch, glucose and inulin on the formation of inulase were determined. Digestion was continued for forty-two hours at the end of which time the amount of inulin hydrolyzed is found to be 92% by fungal preparations from cultures grown on inulin and only 3% by all of the other preparations.

Dox finds that "the amount of the carbohydrate splitting enzyms may be materially increased by cultivating the organism on the corresponding carbohydrate." This is particularly true of inulase, amylase, and lactase, which ordinarily occur only in very small amounts. Dox further finds that "there is no evidence that enzyms not normally formed by the organism in demonstrable quantities can be developed by special methods of nutrition. The influence of adding a particular substratum to the medium is, therefore, not to develop an entirely new enzym, but to stimulate the production of the corresponding enzym which is normally formed under all conditions."

Boselli (1911) has studied the inulase of *Aspergillus niger* with regard to the influence of carbohydrate nutrition on enzyme secretion. Boselli evidently attempts in this work to take into account both the enzymes present in the mycelium of the fungus and in the culture medium. The mycelium after having been removed from the culture flasks is washed and then ground up with sand. The resulting mixture is allowed to digest for some hours, after which the liquid portion is filtered off and used apparently in combination with the liquid of the culture medium as the source of inulase. Boselli finds that the secretion of inulase by *Aspergillus niger* is "notably constant," and that, if equal amounts of various carbohydrates are used in different cultures, the amount of inulase secreted does not vary to any extent. He also finds, as have other investigators, that the amount of enzyme secreted into the culture medium increases rapidly as cultures become older.

Work on the enzyme tannase has given results quite at variance with those obtained from the study of most other enzymes. Fernbach (1890) finds that certain fungi when grown on Raulin's solution in which the carbohydrates are replaced by tannin produce the enzyme tannase. Pottevin (1901) has also extracted an enzyme from fungi capable of hydrolyzing commercial tannin to gallic acid and glucose. This enzyme is not formed except when the fungi are grown on a tannin medium.

Knudson (1913) has undertaken a more extensive study of tannic acid fermentation, studying principally, *Aspergillus niger* and *Penicillium sp.* and finds that these fungi are able to ferment tannic (gallo-tannic) acid, yielding gallic acid as an endproduct. When these forms are grown on a modified Czapek's solution containing tannic or gallic acid, supplemented by sucrose as a source of carbon, they form the enzyme tannase. In the absence of tannic or gallic acid, no tannase is formed. Gallic acid is not as efficient as tannic acid in stimulating the secretion of tannase. Fourteen other substances used as a source of carbon failed to stimulate the secretion of tannase. Experiments, in which a constant amount of sucrose and various amounts of tannic acid are used, show that the greater the amount of tannic acid supplied the greater is the secretion of the enzyme. When a constant amount of tannic acid is employed with varying amounts of sucrose, the increase in the amount of sucrose is found to have an inhibitory effect on the amount of tannase secreted. Media having tannic acid as the sole source of carbon are found to give a maximum secretion of tannase. The amount of tannase secreted is regulated by the amount of tannic or gallic acid present in the substratum and in the absence of these substances, no tannase is formed.

Kylin (1914) has studied the regulatory formation of certain enzymes in *Penicillium glaucum, P. biforme* and *Aspergillus niger*. Investigations were made on the effects of carbohydrate nutrition on the formation of diastase, invertase and maltase. Kylin finds that the work of Katz along similar lines is not without certain defects since he did not consider the reaction of the culture medium or the changes that took place in it during the growth of the fungi. Kylin believes that the acidity arising when glucose is present in the culture medium and the alkalinity arising when ammonia is set free in cultures containing asparagin hinder the action of enzymes produced by the fungus and thus a true index of enzyme formation is not obtained. In no case does Kylin find any evidence of qualitative enzyme regulation, but quantitative enzyme regulation has been noted in a great number of cases. With *Aspergillus niger* diastase is formed when no starch is present,—maltose, quinic acid, mannitose, glycerin and peptone, being used in its stead. Small amounts of starch added to such cultures cause a large increase in the amount of diastase formed and, if the fungus is grown with starch as the only source of carbon, the amount of diastase produced is still greater. Dextrin is found to be quite as efficient as starch.

The results obtained by Kylin in his work on diastase formation in *Penicillium glaucum* are in general similar to the results obtained with *Aspergillus niger*. Small amounts of glucose (0.2%), together with starch, cause an increase in the amount of diastase produced, but if as much as 5% of glucose be added, a decrease in diastase production results. The regulatory secretion of diastase in *Penicillium glaucum* is more marked than in *Aspergillus niger*.

In his work on invertase formation of *Aspergillus niger*, Kylin corroborates the results obtained by Colin (1911) on the effect of glucose. This substance is found to have no influence on the amount of invertase produced. Invert sugar is likewise shown to be without effect. Kylin further finds that, when sucrose is present in the culture medium, the formation of invertase is greatly increased, and that the amount present is greater in cultures two days old than in those that are three days old. The results obtained with *Pencillium glaucum* and *P. biforme* are essentially the same as for *Aspergillus niger*. Glucose is without influence on the formation of invertase but its presence makes the inversion of the sucrose of the culture medium somewhat slower. It is suggested that this may be a case of chemical balance, glucose being one of the end products of the hydrolysis of sucrose.

Kylin finds that the inversion of maltose in the culture medium is similarly hindered by the presence of glucose in it. Maltase is formed not only when maltose is the source of carbon but also when glucose, sucrose, quinic acid or starch are substituted for maltose. The formation of maltase in the presence of maltose is greatly increased but larger amounts of maltose do not result in a corresponding increase in the amount of the enzyme produced. The presence of glucose together with maltose does not cause a decrease in maltase formation. The results of the studies on the two species of *Penicillium* are similar to the results obtained with *Aspergillus*.

Kylin finally concludes that his results give evidence of quantitative enzyme regulation only and no evidence whatever of a qualitative regulation. The results of all workers, who have found a qualitative enzyme regulation with the exception of the work of Knudson on tannase, are questioned by Kylin.

### C. METHODS AND MATERIALS

The correlation of the experiments here presented with those of previous investigators along similar lines made it desirable that a single well known organism, which had been rather thoroughly investigated along other physiological lines, be selected as the main object of study. For this reason and for the reason that it grows well on liquid media, *Aspergillus niger* was selected. This species is readily identified and easily maintained in pure culture, giving it an additional advantage over the use of many other forms. Stock cultures were maintained on ordinary potato-glucose-agar and were transferred regularly in order that fresh spores might be available at all times during the course of the experiments.

All experiments were conducted in Jena glass containers and all water, culture media, etc, were kept in Jena glass. In all experiments, except one, Erlenmeyer flasks of 100 cc. capacity were used for the cultures. In one experiment 250 cc. Erlenmeyer flasks were used. All glassware was thoroughly cleansed and rinsed several times in double distilled water. Great care was taken to obtain distilled water free from all impurities.

Inorganic salts used for culture media were those of Kahlbaum and of Merck and were of a high degree of purity. Merck's anhydrous glucose, maltose, soluble starch and inulin were employed. In certain experiments the inulin used was prepared according to methods described by Haas and Hill (1913, p. 114) and appeared to be of a high degree of purity since it was homogeneous and gave almost no evidence of reducing power. Rock candy crystals were used as a source of sucrose.

The culture medium was that recommended by Kylin (1914) using ammonium nitrate as a source of nitrogen as follows:

| | *per cent* |
|---|---|
| Ammonium nitrate | 0.22 |
| Magnesium sulphate | 0.06 |
| Potassium diphosphate | 0.12 |
| Ferric chloride | Trace |

For convenience in mixing these substances each salt was dissolved separately in a small amount of water. When needed for use the required amounts were measured into a volumetric flask, the carbohydrate added and the whole made up to volume.

Culture flasks were then prepared by running in 25 cc. of the medium from a burette and the solutions were sterilized for three successive days in an Arnold steam sterilizer. This method was substituted for sterilization with the autoclave in order to prevent the hydrolysis of the inulin of the culture medium. It was at first suspected that the use of acid phosphate in the culture medium might result in the hydrolysis of the inulin present but according to Dox (1910) this does not take place.

Various methods for inoculation of the cultures with fungus, spores were tried out with the view of obtaining the most uniform growth possible of the fungus and at the same time avoiding chances of contamination of the cultures. The best results from all points of view were obtained by transferring two loopfuls of spores to each culture flask with a standard platinum loop. The flasks were then thoroughly agitated to give a uniform distribution of the spores.

All cultures were grown in the dark in a room regulated by an electrical thermostat at a temperature ranging from 29.5° to 30°C. Under such conditions, *Aspergillus niger* on a 1% inulin mediun begins to form mature spores after not more than forty-eight hours. At the end of thirty-two hours conidiophores begin to form but cultures are still white and no mature spores are present. On media containing other sources of carbon than inulin, *Aspergillus niger* takes somewhat longer to sporulate. Other fungi grown on the same media and under the same conditions vary considerably in the rapidity of their growth and maturation.

As will be seen from the review of the literature and from the experimental data which will be considered later, the period at which the mycelium is richest in enzyme content, is at the beginning of sporulation. This is apparently the time of greatest metabolic activity of the fungus. At this time the mycelium was removed and washed until tests with Fehling's solution no longer showed the presence of reducing sugar from the culture medium, in the wash water. It is believed that this amount of washing was sufficient to remove all but traces of the culture medium from the mycelium. The mycelium was then pressed between pieces of filter paper to remove the free water present and treated according to a modification of the method used by Bartholomew (1914) in his study of the enzymes of certain marine algae. This method consists in immersing the water free mycelium for twenty minutes in 95% alcohol, then removing the excess of alcohol by means of filter paper and immersing it in acetone for ten minutes and a second time for two minutes. The excess of acetone having been removed, the material was spread out and dried at a temperature of 40°C. The material, which by this process is practically completely dehydrated, was allowed to remain at this temperature until it was to be used, when it was cooled in a desiccator, carefully weighed and finely ground up with fragments of Jena glass in a mortar. The pulverized mycelium was then placed in flasks and water added in proportion to its weight so that all the units of the experiment contained the same dilution of mycelium. After thoroughly shaking the flasks, extraction was allowed to proceed for twelve hours in an ice-chest. This precaution was taken to inhibit so far as possible any bacterial growth. No attempt was made to utilize the enzyme content of the culture medium for reasons discussed elsewhere.

The amount of dehydrated mycelium available varied considerably in different experiments so that it was not found feasible to run all experiments with enzyme solutions of equal concentration, but it is believed that, since all the units of one experiment were of equal concentration so far as the weight of mycelium used is concerned, the results obtained give conclusive evidence of the difference in enzyme activity between the units of that experiment.

All solutions throughout the course of the experiments were measured at room temperature.

Experiments on inulase were conducted in 250 cc. volumetric flasks. One hundred cubic centimeters of a 1% inulin solution were measured into each flask from a burette and to this solution was added a definite amount of enzyme solution. The flasks were made up to volume, thoroughly shaken and toluene added. They were then placed in the thermostat at 40°C. for a definite time which varied in different experiments. The first experiments performed were allowed to stand for from twelve to eighteen hours, but it was feared that bacterial or autolytic changes might occur in that length of time and so later experiments were run for a period of four hours only.

Various controls were run parallel with the experiments. Boiled enzyme extract was added to inulin solution in every case. Solutions of the unboiled enzyme extract alone were also allowed to stand during the time of the experiment and tested for reducing sugar. To determine if possible whether or not zymase from the mycelium might possibly break down some of the reducing sugar formed, fermentation tubes containing inulin and the enzyme extract were set up to detect the possible evolution of $CO_2$. These checks in all cases gave negative results and for this reason all of them except the first form were abandoned. It was, however, found that inulin solutions of a strength equal to that of the experiments possessed a low-reducing power, after standing for the time of the experiment, and this amount was subtracted from all results. After being incubated for the required time, the flasks were heated to the *boiling point* to arrest enzyme action, cooled to room temperature and again made up to 250 cc.

The activity of the inulase tested was judged by the amount of reducing sugar present at the end of the incubation period. This was determined by use of Fehling's volumetric method (Haas and Hill, p. 75), and later a similar experiment was conducted using the Fehling gravimetric method (Haas and Hill, p. 85). The volumetric method of analysis offers some difficulties, when carried out in the presence of inulin, due to a slight hydrolysis of the inulin if boiling with the alkaline Fehling's solution is continued for any considerable time. For all practical purposes, this difficulty is avoided if the solution to be analyzed is added rapidly nearly up to the end-point. By rapid manipulation an end-point which checks within a fraction of a percentage may be obtained.

It was, however, thought best to repeat the experiments by the gravimetric method in order to have a check on the work. This method gave results which check rather closely and from their general similarity to the results obtained by the volumetric method there seems to be little reason for believing that the results obtained are not reliable. All analyses, both volumetric and gravimetric, were run in duplicate and the results computed according to factors given by Haas and Hill.

# EFFECT OF BOG AND SWAMP WATERS ON SWELLING IN PLANTS AND IN BIOCOLLOIDS[1]

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Direct effects of the waters of bogs and swamps in producing modifications of growth, departures in structure and form and in influencing general nutrition are well established and have long been known. The numerous analyses of the water have failed to disclose physico-chemical features which might be held responsible for the very direct and positive action exercised in the determination of the plant formations of such places. The history of such attempts is a long one and need not be rehearsed here, as this was admirably done at the San Diego meeting of this Society.[2] The most recent contribution to the subject is that by Clements who found that some of the effects of bog water disappeared with its oxygenation.

One need not go very far into the main problem to be made to realize that many of the unsolved questions are not to be attributed to a lack of knowledge of the composition and properties of the waters, but to a failure to understand certain features in nutritional physiology and growth, notably the water-relations. The present paper includes the results of some studies in imbibition which were undertaken primarily for the purpose of determination of the principal physical factors in growth but which have been extended to a general consideration of swelling in protoplasm as affected by its own composition and by various solutions.

In the effort to analyze growth and to identify some of its more important constituent processes it was reasoned that if the materials which make up the protoplasm of a plant were combined in the form of an elastic gel such a mass should show water-relations similar to those of the plant. This reasoning was justified by actual experience.[3] Diversified experimentation leads to the conclusion that a mixture of 80 to 90 parts of agar and 10 to 20 parts of albumen, gelatine, or albumen derivatives impregnated with the nutrient salts in a proportion decreasing to the vanishing point, simulates the swelling action of the protoplasm of roots and stems of the higher plants tested.[4]

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[1] Presented at the meeting of the Ecological Society of America, Pittsburg, Jan. 1, 1918.

[2] See Rigg. Summary of bog theories. Plant World, **19**: 310. 1916.

The chief organic constituents may vary so widely in amount however that the proteins may be present in greater proportion, as in the case of pollen cells, or in bacteria in which the albumen content is very high. The proportions of the amorphous carbohydrates and proteins, the concentration of the included salts acidity, temperature, viscosity, previous history, and the composition of the solutions in contact with the protoplasm are all features which play a part in determining the amount and nature of the swelling. The swelling of biocolloids and of plants may therefore be expected to yield suggestions as to the character of the solutions in which it takes place.

The general methods of preparing the biocolloids has been described in the two papers to which reference has been made. The completion of the preparation puts the experimenter in possession of dried plates from which small sections, 3 by 4 mm. and not more than 0.2 mm. in thickness, may be cut. A trio of these may be placed in a stender dish and subjected to the action of water or solutions in the same manner as sections of living and dried plants may be treated.

Bog water was furnished by Mr. E. R. Long, who procured a sample from Ronalds, in the region of Seattle, Washington. Mr. J. M. McGee of the Department of Chemistry of the University of California, reports the following constituents:

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[3] See MacDougal and Spoehr. Growth and imbibition. Proc. Amer. Phil. Soc., **56**: 335–338. 1917.

[4] See MacDougal and Spoehr. The effects of acids and salts on biocolloids. Science, **42**: 269. 1917.

| | Per liter gram |
|---|---|
| Soluble organic matter | 0.106 |
| Ash (chiefly $CaSO_4$) | 0.048 |
| Total soluble residue | 0.154 |
| Reaction neutral | |

Swamp water was procured by the kindness of Dr. S. A. Gortner, who obtained a sample from near Anoka, Minnesota, concerning which he says,

> This sample was taken about 20 miles north of Minneapolis in Anoka County, of which three-fourths of the area consists of peat lands. These peat lands are of the grass and sedge formation, the peat being from 4 to 6 inches or more deep, fairly well decomposed and one of the better grades of peat for agricultural purposes in that it contains an appreciable amount of lime. I believe that you will find this sample of water perfectly typical of most of the large grass bogs of Minnesota.

The analysis of this water shows the following:

| | Per liter gram |
|---|---|
| Soluble organic matter | 0.094 |
| Ash ($CaSO_4$ with trace of NaCl) | 0.128 |
| Total soluble residue | 0.222 |
| Reaction neutral | |

The first trials of the action of these waters was made with living material. Circular disks 12 mm. across and of an average thickness of 11 to 13 mm. were cut out from joints of *Opuntia discata* which had matured at Carmel, California, in the summer of 1917. Trios of these sections were placed in small stender dishes and a triangular sheet of glass was placed over them. The vertical arm of an auxograph was adjusted so that its lower end rested in a ground socket in the center of the glass plate. The pen was adjusted to the zero line of the record sheet and when the dishes which had a capacity of 25 cc. were filled with a solution, the average increase of the thickness of the three sections was recorded. All of the records given in this paper were made with liquids ranging in temperature between 13.5°C. and 15°C. unless otherwise specified. The first set of measurements of swelling of *Opuntia* comprises the following data:

| DISTILLED WATER | BOG WATER | SWAMP WATER | CALCIUM NITRATE, 0.008 M |
|---|---|---|---|
| *per cent* | *per cent* | *per cent* | *per cent* |
| 18.2 | 18.3 | 13.6 | 15.5 |

The calcium nitrate solution is of the concentration in which this salt enters into nutrient solutions. All measurements were closed at the end of forty hours. Some swelling was still in progress, but the rate of increase in the swamp water had approached the end point or zero.

The equivalence of the effects of distilled water and of bog water is obvious and the lessened swelling in swamp water is also demonstrated, while the swelling is greater in calcium nitrate solution than in the swamp water.

Another series was carried out in which sections of *Opuntia* were swelled at temperatures of 18 to 20°C. in acidified and salt solutions. It is to be noted here that while rise in temperature retards imbibition in simple gels, yet this law cannot apply directly to the swelling of biocolloids or living plants. The measurements of swelling of *Opuntia* in various solutions at the given temperature was as below:

| SWAMP WATER | SWAMP WATER, CITRIC ACID 0.01 M | POTASSIUM NITRATE, 0.01 M |
|---|---|---|
| *per cent* | *per cent* | *per cent* |
| 14.4 | 14.9 | 14 |

| CITRIC ACID | POTASSIUM NITRATE, CITRIC ACID, 0.01 M | POTASSIUM HYDRATE, 0.01 M |
|---|---|---|
| *per cent* | *per cent* | *per cent* |
| 7 | 9 | 12 |

The measurements in swamp water alone and with acid include the full increase in ninety-six hours while the others extended over from twenty to forty hours.

No important effect can be ascribed to the acidification of swamp water. The swelling of the sections in the hundredth-molar solution of potassium nitrate was but little below that in the swamp water but when this solution was similarly and equally acidified, a decrease ensued.

The foregoing tests were made with sections in a living condition in which questions of permeability and osmotic action might possibly play a part. Material was prepared to exclude the action of the living cell. The chlorophyllous layers were removed from the two sides of joints of *Opuntia* and slices, 7

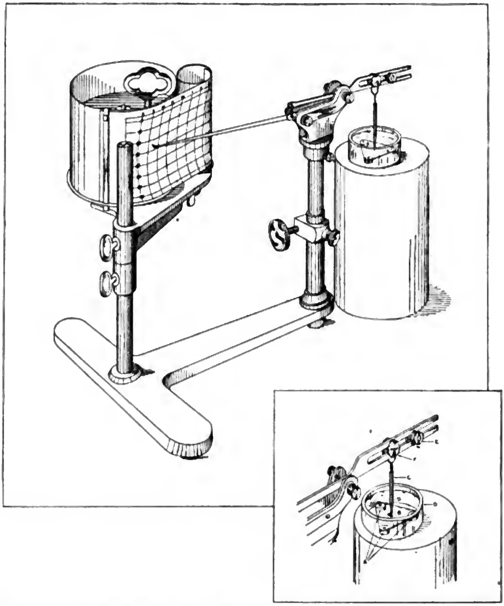

Fig. 1. The use of the improved model of auxograph in measurement of swelling of sections of plants and of biocolloids.

mm. in thickness, were cut in the plane of the joint and placed between two sheets of filter paper to one of which they adhered. A second sheet was laid over them and the preparation placed on a wire netting to dry without pressure. In six days the thickness had been reduced to about 0.5 mm. and enough moisture still remained to give the slices a leathery consistency. Suitable sections free from visible fibrovascular tissue were prepared which gave swellings as follows:

| DISTILLED WATER | BOG WATER | SWAMP WATER | NUTRIENT SOLUTION 0.5 |
|---|---|---|---|
| *per cent* | *per cent* | *per cent* | *per cent* |
| 660 | 640.0 | 530 | 625.0 |
| 47 | 45.5 | 38 | 44.3 |

These measurements were taken at the end of twenty-four hours when a fair rate of increase was still noticeable which would in the end have carried the figures up to the next hundred in the upper lines which gives the swelling in percentages of the thickness of the dried sections. The lower line shows the proportion to the original measurements of living material. The swelling in bog water is but little less than in distilled water and is also but little different from that in the nutrient solution, which is of the concentration used in water cultures. Hydration is however noticeably less in swamp water.

The nutrient solution used in all of these tests was one made up after Tottingham's formula including four salts as follows: Potassium nitrate 1 M, di-potassic phosphate 2.38 M, magnesium sulphate 2.97 M and calcium nitrate 2.95 M.

Attention was now turned to the biocolloids to ascertain whether the action of plant material living and dried would find a parallel in the action of mixtures of known composition. Sections of plates composed of agar (90) and oat-protein (10) were found to show the following swellings at 15°C.

| DISTILLED WATER | BOG WATER | SWAMP WATER |
|---|---|---|
| *per cent* | *per cent* | *per cent* |
| 2188 | 2083 | 1200 |

The decreased swelling in swamp water and the high swelling in bog water were marked and invariable.

The biocolloid approaches more nearly to the condition of the protoplast however when in common with all living matter it includes some salts. The above mixture treated with nutrient salts was not available, but some plates in which the oat-protein was replaced by bean-protein to which had been added 0.8% of nutrient salts were swelled in a parallel series. The untreated mixture free from the added salts does not show as high a capacity as that made up with the oat-protein. The measurements of the increase of the agar-bean-protein-salted sections at 15°C. were as follows:

| DISTILLED WATER | BOG WATER | SWAMP WATER | CALCIUM NITRATE, 0.008 M |
|---|---|---|---|
| *per cent* | *per cent* | *per cent* | *per cent* |
| 1525 | 1525 | 1100 | 825 |

These measurements were taken at the end of forty hours while some increase was still in progress, but the final relations would not have been materially altered by the use of the end points for the comparisons. The retarding action of the swamp water and the equivalence of swelling in pure water and bog water therefore runs plainly defined through all of the experiments with living and dried sections of plants and in tests with salted and unsalted biocolloids. Calcium nitrate in the concentration used exercises a more marked effect on the salted biocolloid than on the unsalted mixture and on the plant material. The calcium content of the biocolloid is probably much higher than that of the plant so that the two sets of measurements are not strictly comparable.

The calcium solution contained about eight times as much salt as the bog water and nearly three times as much as the swamp water which also includes a trace of sodium chloride. A series was therefore arranged to compare the action of the two with equivalent salt solutions. Sections of agar and bean-protein impregnated with 0.8% of nutrient salts were swelled at 15°C. with results as follows:

| DISTILLED WATER | BOG WATER | CALCIUM SULFATE 0.048 GRAM PER LITER | SWAMP WATER | CALCIUM SULFATE 0.128 GRAM PER LITER |
|---|---|---|---|---|
| *per cent* | *per cent* | *per cent* | *per cent* | *per cent* |
| 1417 | 1444 | 1417 | 944 | 1083 |

Bog water and an equivalent calcium solution allow equal swelling, but the increase in swamp water is much less and also less than in the equivalent calcium solution to which may be attributed most of the retarding effect of the swamp water.

The capacity of the biocolloids varies with the proportion between the carbohydrates and the proteins and protein derivatives. A mixture was now made up which contained not only a high nitrogen content but a second carbohydrate, while five albuminous compounds were included. For this purpose 70 parts agar, 5 parts each of dextrose, peptone, gelatine, asparagin, nucleinic acid and bean-protein were suitably liquefied and poured into plates which dried down to a thickness of 0.2 mm. Swellings of sections of these plates at 15°C. gave the following increases at the end of twenty-four hours.

| DISTILLED WATER | BOG WATER | SWAMP WATER | CALCIUM CHLORIDE, 0.2 M | CALCIUM CHLORIDE, 0.1 M |
|---|---|---|---|---|
| *per cent* | *per cent* | *per cent* | *per cent* | *per cent* |
| 725 | 592 | 550 | 350 | 400 |

The total swelling in distilled water for this biocolloid is low although it is to be noted that swellings as high as 1200% in distilled water have been measured at temperatures of 18 to 20°C.

Sections from plates made up as above but to which had been added 0.8% of nutritive salts gave increases as follows at temperatures of 15°C.

| DISTILLED WATER | BOG WATER | SWAMP WATER |
|---|---|---|
| *per cent* | *per cent* | *per cent* |
| 600 | 525 | 625 |

This complex biocolloid high in nitrogen and in the nutritive salts displays a capacity in swamp water superior to that shown in bog water or pure water. The properties in question would enable a plant so equipped to thrive in the waters of swamps and it would be interesting to determine whether such a condition actually prevails in the plants of the sedgy swamps.

The earlier attempts to interpret the swelling action of protoplasm were founded on the assumption that such increase might be represented by the action of gelatine. The unsoundness of this assumption and the inadequacy of the methods using this material have been amply demonstrated by results previously published. At one end of the scale stand some plants and some plant structures high in protein compounds and low in pentosans and these do show a behavior approximating that of gelatine. This is illustrated by the following series in which sections of gelatine plates 0.18 mm. in thickness were swelled at 15°C. giving measurements as follows:

| DISTILLED WATER | BOG WATER | SWAMP WATER | NUTRIENT SOLUTION, 0.5 | POTASSIUM NITRATE, 0.01 M |
|---|---|---|---|---|
| *per cent* | *per cent* | *per cent* | *per cent* | *per cent* |
| 778 | 839 | 939 | 889 | 911 |

The swelling of sections of agar plates 0.2 mm. in thickness at 15°C. resulted in increase of

| DISTILLED WATER | BOG WATER | SWAMP WATER | NUTRIENT SOLUTION, 0.5 |
|---|---|---|---|
| *per cent* | *per cent* | *per cent* | *per cent* |
| 700 | 650 | 425 | 375 |

It is to be seen that all of the solutions decrease the swelling capacity of the agar below that displayed in distilled water, and that the greater reduction in the nutrient solution is to be attributed to the higher salt content.

Plants of bogs and especially swamps are undoubtedly subjected to great variations in the composition of the water by reason of inundations and floods. It was therefore thought pertinent to extend experiments begun in 1916 in which alternations of solutions were made in such manner as to test the effect of previous history on the behavior of a biocolloid. Sections of agar-oat-protein 0.18 mm. in thickness swelled 972% in twelve hours at 17 to 19°C. and reached a total of 1233% at the end point in one hundred and eight hours which are equivalent to results previously attained and hence afford a fair basis of comparison with the following, in which a trio of sections swelled 2361% in distilled water at the end point in seventy-two hours. Replacement of the pure water with swamp water was followed by a slow shrinkage which however amounted to only 36% of the original volume. No swelling agent yet tested has been found to reverse the action of another solution so fully as to bring the dimensions of the sections down to the dimensions which might be attained in the second agent alone.

Sections of a biocolloid consisting of 90 parts agar, 10 parts of bean-protein, to which 0.8% of nutrient salts had been added, 0.18 mm. in thickness were now swelled in swamp water at 18 to 20°C. The increase was measured at the end of sixteen hours, at which time the total swelling was 1082%. The swamp water was now replaced with hundredth-molar citric acid—potassium nitrate for thirty-six hours during which time no appreciable change was registered. Replacement of this solution with swamp water was followed by a resumption of the swelling which carried the thickness of the sections to 1388% of the original which is greater than that attained in the simple continuous swelling in swamp water.

Swamp water is high in salts and it is probably this feature to which its influence on swelling is due. A test parallel to the above was made in which the sections were first swelled in a 0.5% nutrient solution in which the salts are somewhat more concentrated than in the swamp water. A swelling of 888% took place in seventeen hours, at which time the pen of the auxograph was tracing a horizontal line. Replacement of the nutrient solution with the acidified potassium nitrate solution was followed by a very slight swelling. When the salt solution was replaced by swamp water an increase of 333% followed in forty hours. The two tests were parallel except that the initial treatment in one case was with nutrient solution in which the salts were more concentrated than in the swamp water used in the other. The final swelling in the second case is greater and may be attributed to the initial salt action.

In a partial repetition of the above test the sections placed in nutrient solution swelled 861% in twenty hours. Lengthening the immersion in acidified potassium nitrate to fifty-five hours was accompanied by a swelling of 55%. Replacement with distilled water set up a slow increase which resulted in a gain of 111% in thickness in forty hours. The total increase was 1027%, while the one finished in swamp water swelled 1388%.

The relative effects of swamp and bog water on biocolloids were tested in still another way. Plates of agar-oat-protein were prepared in which strips of webbing of cotton were imbedded in the soft material as it cooled for the purpose of testing the influence of certain purely mechanical features on swelling. Portions of the plates dried down to a thickness of 0.18 mm. in the clear portion of the plate and sections from this swelled 2111% in bog water and 1195% in swamp water at 15°C. Sections containing webbing were 0.58 mm. in thickness and the actual increase of such sections was 491% in bog water and distilled water and 371% in swamp water. If the increase be calculated on the assumption that the webbed sections included as much biocolloid as the free sections the proportions would be 1583% in bog water and distilled water and 1195% in swamp water.

The foregoing paragraphs describe a series of tests made for the purpose of determining the effects of the water of sphagnum bogs and sedgy swamps upon plants. Detailed analyses of water characteristic of both habitat have long been available, but it has not been possible to explain some of the more marked effects, on the basis of such information.

An effort has been made to find such an explanation by further studies of the mechanism of hydration of protoplasm. Living matter swells in solutions in the same manner as biocolloids consisting of salted mixtures of varying proportion of agar and protein or albuminous derivatives. The swelling of biocolloids and of living and dried sections of plants in distilled water, bog water, and in a calcium solution of the same concentration as the bog water are practically equal. So far as known to the writer the effects of bog water are not attributable to any of its known constituents, and its low oxygen content as tested by Clements may be responsible for its morphogenic and physiological effects and its domination as a factor in the habitat.

Swamp water has been found to affect absorption and swelling in the same manner as an equivalent solution of calcium sulphate. Swelling and absorption are retarded by swamp water in salted biocolloids and in sections of plants containing a large proportion of pentosans and a low protein content. Biocolloids with a high protein and salt content on the other hand show an enhanced absorption in swamp water. Inferentially, plants of similar constitution would carry on absorption readily and thrive in swamp waters. Whether adaptation to swamp habitats actually takes this course is not known.

# BOOKS AND CURRENT LITERATURE

Fossil Plants.—This third volume of Seward's[1] work, appropriately dedicated to the late Professor Zeiller, is separated from vol. ii by an interval of seven years, and from vol. i by nineteen years. Naturally in a work extending over so long a period of time much unevenness of treatment will be unavoidable, and while the long delay is not without recompense in the amount of new material that it has been possible to include, it scarcely adds to a synoptic presentation. We are told that vol. iv, which concludes the work, is now in press and will be issued very soon.

This has been a noteworthy undertaking and the results in certain directions are altogether admirable. There can be no doubt of the usefulness of the book, particularly in the case of mature students and professional morphologists. The author has a wide acquaintane with the literature, especially in the field of morphology, and if the book did not seem to be pervaded with an air of didactic omniscience it would be ungracious to criticize it. The unevenness of treatment is the chief defect. It is impossible to discover any method of selection of matter—unimportant and doubtful objects are discussed, particularly if they happen to be British, as for example the fossilized phloem that has been christened *Vectia*, while more important material is not even mentioned. In a large work one expects a well formulated method of selection or an avowed purpose of ignoring a part of the field in which the author is on unfamiliar ground. Perhaps the author does not have any such feeling, but certainly the anatomical part in which his chief interest has hitherto lain is exceedingly well done and cannot be criticized, except as differences of opinion naturally exist in the interpretation of various structures. When, however, he deals with Paleozoic seeds preserved as casts and impressions, or with fronds of cycadophytes and similar classes of remains, the work abounds in errors of omission and commission, and presents a very incomplete picture of this aspect of the subject. I have, in another place, dwelt upon some of these points at considerable length. They weaken the book's influence from the stratigraphic or truly historical side. In the present notice, however, designed for botanical readers, I wish to confine what I have to say to the phases of the present volume that are of most interest to them, what I have already said being sufficient to put them in a critical frame of mind toward statements the validity of which need testing.

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[1] Seward, A. C., Fossil Plants, vol. 3i Cambridge Biological Series, xviii + 656 pp. 629 figs. Cambridge, University Press, 1917 ($4.50).

The volume opens with a very satisfactory chapter devoted to a discussion of existing cycads, largely an abstract of already published data. Then follow three chapters devoted to the Pteridospermae. These are divided into three families—the Lyginopteridae, Medulloseae and Steloxyleae, and are rather fully and very satisfactorily discussed.

The remaining structural forms that are probably more or less closely related to the foregoing pteridosperms are considered to represent the following seven families:—Megaloxyleae, Rhetinangieae, Stenomyeleae, Cycadoxyleae, Calamopityeae, Cladoxyleae and Protopityeae, and these are discussed in a separate chapter under the group term of Cycadofilices. These presumable pteridosperms, because of the dearth of conclusive evidence are thus arbitrarily segregated. While caution is to be commended in dealing with fragmentary plant fossils it may be questioned whether judgment may not be suspended until it dies of inanition. It is also questionable how far it is desirable to introduce purely artificial groups, and if it be granted as desirable, it may be pertinent to ask what criteria are to decide such a question. That such a course does not make for clearness and that such questions rest after all upon personal equation rather than upon objective facts may be illustrated by Seward's reference of the genus *Steloxylon* to his Pteridospermae and the scarcely to be distinguished genus *Cladoxylon* to his Cycadofilices. The fact that so many of the so-called families of the latter group are monotypic is convincing enough evidence that they illustrate chance discoveries and the imperfection of the geological record rather than that they were really monotypic. Following the chapter devoted to the Cycadofilices there are two chapters dealing with the Cordaitales, which are described under the three groups of Poroxyleae, Cordaiteae and Pityeae. The statement on page 276 that there is no proof of Cordaites in the Arctic may be a statement of opinion—it is hardly a fact. Similarly the statement that it is not certain that Cordaites flourished before the Carboniferous is also a matter of opinion and not of facts. There is abundant proof of the existence of Cordaites-like forms in the Devonian.

A succeeding chapter of 65 pages is devoted to Paleozoic gymnospermous seeds and in this there are many things to take exception to, although the parts describing the results of the morphological investigations of the British and French students of petrified materials are, on the whole, very well done. The remainder of the book is taken up with the description of fossil Cycadophytes. These are very well handled and give a satisfactory summary of the present state of our knowledge, although the concluding chapter, that dealing with the frond genera, is much abbreviated and not especially noteworthy, as I have already remarked.

Unless one reads with discrimination one will gather the idea that the Mesozoic flora was dominated by plants of the type of Cycadeoidea. This is rather wide of the mark. The Cycadeoideas are significant chiefly because their wonderful preservation has enabled Wieland and others to unravel the details of their structures so that they have become the key to our understanding of Mesozoic Cycadophytes. They are probably less important from a phylogenetic standpoint than such forms as *Wielandella* or *Williamsoniella*. It is moreover extremely doubtful if the Cycadeoideas were ever much more of a dominant element in the Mesozoic floras than are the existing cycads in the Recent flora. They represented a very much specialized side-line without issue, while the really important Cycadophytes of the Mesozoic were those forms which Wieland has grouped together under the name of the Williamsonia tribe. In these, while the fructifications were morphologically like those of Cycadeoidea, the habit was very different, and it is these forms that approach the ancestral Pteridosperms on the one hand, and types like the Ginkgoales on the other. It seems probable that the bulk of the frond genera belonged to the Williamsonias rather than to the Cycadeoideas. Seward is hardly justified in doubting the bisexual character of the so-called flowers of *Cycadeoidea Gibsoniana*, nor is it easy to follow him in his explanation of the supposed corona of *Williamsonia gigas* as, morphologically, a whorl of connate stamens in a central terminal position. When it is remembered that throughout all of the Cycadeoidea species already investigated the megasporophylls become more or less sterile distad and that in some species, as Wieland has demonstrated, these, together with the prolonged interseminal scales are modified to form a mop-like tuft at the apex of the receptacle, and also having in mind the ears or wings of the microsporophylls that formed a canopy over the apex of the receptacle in *Cycadeoidea colossalis*, it is quite possible to explain Seward's figures 546 and 547 in a variety of ways without recourse to the improbable hypothesis that we have terminal microsporophylls. In fact, there is no evidence that the so-called microsporophylls of *Williamsonia gigas* described on page 435 belonged to that species. Fig. 549 no doubt represents a synangia-bearing disk of a *Williamsonia*, but there is not the slightest evidence that it belonged to *Williamsonia gigas*, or that it should be placed on the end of a *Williamsonia* carpellary receptacle. Similarly the sterile disks or infundibuliform organs have not been demonstrated to have been borne on the apex of the receptacle.

Professor Seward's position on the difficulty of founding well marked botanical species upon material that is preserved as impressions is well known and often sound. However, this does not justify the assumption that all fossils that are superficially similar belonged to the same species regardless of geographical position or geological horizon. Such a method of treatment, well illustrated in Seward's Jurassic flora, entirely obscures whatever real value such fossils may have for purposes of deduction concerning geographical distribution, the problems of paleogeography growing out of distribution, and the bearing of fossil plants upon stratigraphy.

On page 278 the genus *Pelourdea* is proposed for the long known *Yuccites vogesiacus* of Schimper and Mougeot because the author considers it undesirable to retain a designation suggesting false ideas with regard to affinity. No one now supposes that this is suggested and such a proposal is entirely unwarranted and can only be confusing instead of clarifying. Moreover it is flying in the face of all canons of nomenclature. A name of a genus is simply a name, and we use generic names for convenience chiefly, and not in a descriptive or phylogenetic sense. I imagine that fully 25 per cent of the names in systematic botany and zoology are equally inappropriate for one reason or another but this does not afford any justification for attempting to replace them. There is surely a difference between retaining a degree of personal independence in the face of codes and the persistent refusal to recognize the fact that practices of this sort serve only to confuse the subject.

The proof-reading of the present volume is not as good as in the preceding volumes, a number of the illustrations are unusually poor and some might better have been omitted. Nor is the bibliography reasonably complete. The latter like the text shows no method of selection and appears to have just happened in the form in which it is printed.—EDWARD W. BERRY.

BOTANY OF CROP PLANTS.—The author and the publishers are to be congratulated on the contents and the general appearance of this useful publication. It concentrates in convenient and simple form many facts that make it useful either as a text or reference book. In general make up it resembles another recent publication of this firm, Harshberger's Mycology and Plant Pathology.

As indicated by the title the book treats chiefly of plants grown by man for his own use, and as food for his stock. Were it not for such prominent exceptions as cotton, flax, hemp, hops and tobacco, it might be called the Botany of Food Plants. Drug and ornamental plants are not included though more or less grown as crops in some districts. The plants dealt with are those grown in the United States, and evidently more attention was given to those congenial to temperate regions than to those tropical or semi-tropical in nature. The date is entirely neglected. Some four hundred botanical species and varieties are treated more or less in detail, not counting many horticultural varieties.

The first part of the book, eight chapters, is devoted to a brief description of the morphology and histology of plant structures. This is given to make more intelligent the systematic and economic discussions in the remaining thirty-two chapters. These are taken up with a consideration of the most important economic families, genera, and species, beginning with Gramineæ and ending with Compositæ, in orthodox botanical style but in a popular manner. Of course the Gramineæ receive the most attention and Robbins, true to American tradition, evidently considers corn King, for it receives the greatest space, some thirty-four pages, though wheat and potatoes are rival candidates for this honor. *Malus* and its relatives receive much more attention than *Citrus*, which would tend to make the work more popular in the state of Washington and the north than in California and the south.

Each family, genus and species receives popular botanical treatment from a morphological and systematic point of view, followed by information as to varieties, harvesting, manufacturing, uses, distribution, origin, etc. The illustrations are well chosen and varied. Scientific and common names are used in proper proportions. The whole concludes with an extended glossary and a complete index.—G. P. CLINTON.

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[1] Robbins, Wilfred W., The Botany of Crop Plants. Philadelphia, P. Blakiston's Son and Company, 1917 ($2.00).

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# ON THE OCCURRENCE OF PINUS BANKSIANA IN SOUTHEASTERN MINNESOTA

C. O. ROSENDAHL AND F. K. BUTTERS
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The main pine forests of Minnesota occur to the northeast of a line drawn, roughly speaking, from near the northwestern corner of the state in a southeasterly direction to the Wisconsin boundary at about latitude 45°30′. This line is not straight but shows a marked convexity towards the southwest, amounting to about 75 miles in its middle portion. In the northwest the pine woods come within 50 miles of the North Dakota boundary, being there separated from the prairie country by a strip of deciduous forest and brush 15 to 35 miles in width. The greatest southwestward extension of the pine forest is just back of a great series of lakes running in a southeasterly direction through Becker, Douglas, and Otter Tail counties. In the southeast the boundary runs in a nearly straight east and west direction immediately south of the 46th parallel of latitude. (See map of forest areas.) A few miles east of the Wisconsin border it again turns to the southeast and extends in that direction to the south central part of Wisconsin. The deciduous forest belt to the west and south of the pine woods, which is very narrow in the north, widens considerably southward and about latitude 45° reaches a maximum width of over 100 miles.

The original distribution of the three species *Pinus Strobus* L., *P. resinosa* Ait., and *P. Banksiana* Lamb., within the evergreen forest area was determined largely by soil conditions. The Jack Pine (*P. Banksiana* Lamb.) occurred most abundantly on sandy outwash plains, such as those which extend from Mille Lacs westward nearly to the boundary of the pine area, and in the great paleozoic sand plains of central Wisconsin. The white pine (*P. Strobus* L.) was found particularly on the more clayey soils

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of glacial moraines—in the richest soils often mixed with deciduous trees. The Norway pine (*P. resinosa* Ait.) occupied the intermediate types of soils and mingled more or less freely with both the other species.

Of the three species of pine in Minnesota, *P. Strobus* L. is the one most capable of maintaining itself outside the evergreen forest area and of forming isolated outposts. Numerous such patches occur down the valleys of the St. Croix and Mississippi Rivers as far south as middle Iowa and westward on many of the tributaries of the Mississippi, 30, 40, and in a few cases even 50 miles back from the main valley.

For the most part these outposts consist of a few trees, usually perched on rocky ledges toward the top of the river bluffs, but now and then they form almost pure groves an acre or more in extent. Occasionally single isolated trees occur in the dense, deciduous forest of the north-sloping hills, but in general there is no such general and intimate admixture of white pine and deciduous trees as is common in parts of Wisconsin and Michigan and in southern New England. So far as the authors have been able to ascertain there are about thirty of these isolated patches of white pine in southeastern Minnesota today. (See map.) In a few of these only old trees have been observed, but in most of them a few younger trees and seedlings occur, so that left to themselves, they would in all probability maintain themselves indefinitely.

The other two species behave quite differently from the white pine in their distribution. *Pinus resinosa* Ait. stays well within the general pine area except in the valley of the St. Croix River in the vicinity of Taylor's Falls, where, with the other two species, it forms an outpost a few miles beyond the general border of the evergreen forest, growing on the exposed pre-cambrian diabase in the river valley. The white and Jack pines, therefore, form the skirmish line along practically the whole boundary of the pine area, but it is very seldom that outposts of the latter appear beyond the general area. In fact, up till the summer of 1915 only three such stations were known, all of them less than 15 miles from the main pine line. (See map.)

In June, 1915, a grove of Jack pine was found about 3 miles west of Rushford in the Root River valley, near the southestern corner of the state. This station is about 120 miles southeast of the previously known limit in Minnesota and about 50 miles southwest of the nearest place where Jack pine is known to us to occur in Wisconsin. The grove is situated just west of the western edge of the driftless area. It lies on a north-sloping hillside which is built up from disintegrating paleozoic sandstone so that the soil is very similar to that of the typical Jack pine country of north central Minnesota and central Wisconsin. The grove is 5 or 6 acres in extent and contains several hundred trees of all ages and sizes, with numerous seedlings. One part of the grove is almost a pure stand of pine (see figure), while other parts contain a considerable admixture of scarlet oak and poplar with undershrubs of *Corylus americana* Walt., *Rubus idaeus* L. var *aculeatissimus* Regel & Tilling, *Ilex verticillata* (L.) Gray, and *Cornus* sp. Most of the pines range from 7 to 12 inches in diameter and 40 to 55 feet in height. There are also a

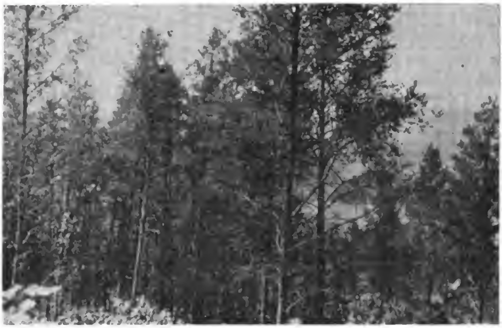

Fig. 1. Isolated grove of Jack pine (*Pinus Banksiana*) in southeastern Minnesota

few larger individuals, some of them old and broken by the wind, which attain diameters of 14 to 16 inches.

In some of the largest trees cuts were made to a depth of 2½ to 3 inches and fifty to sixty yearly rings were counted. Granting that the growth was much more rapid in the earlier periods of the life of the trees it is safe to estimate that these individuals ranged in age from ninety to over one hundred years. One old stump. about 12 inches in diameter and probably cut some ten years ago, showed over ninety rings. This clearly proves that the grove is not a planted one for the neighboring country was first settled by white men in the early fifties of the last century.

That the grove is a natural one is further attested by the fact that associated with the pines are a number of species of herbs and shrubs which occur typically with the Jack pine in the north. The most noteworthy of these are *Oryzopsis pungens* (Torr.) Hitch., *Carex siccata* Dewey, and *Vaccinium pennsylvanicum* Lam. The first two of these have not been found previously in Minnesota outside of the pine area. Other species found in the grove, which grow most abundantly in northern Minnesota, are *Chimaphila umbellata* (L.) Nutt., *Hepatica americana* (D.C.) Ker., *Houstonia longifolia* Gaertn., and *Lupinus perennis* L. A number of the above named species occur abundantly with the Jack pines in Wisconsin, 50 to 60 miles to the northeast, and appear to be natural concomitants of the Jack pine forests of Minnesota and Wisconsin.

These facts all prove conclusively that the grove in the Root River valley, lying 50 miles outside the present limits of continuous pine forests, is a patch of natural Jack pine forest which has in some way become isolated and has succeeded in maintaining its existence in all probability since glacial times. In attempting to account for the presence of this grove in southeastern Minnesota, together with the twenty-six to thirty scattered occurrences of white pine, the most plausible explanation is that they are all relics of a former general distribution of pine forests throughout this area of the state.

The southeastern part of the state now covered by deciduous forest, or more correctly speaking, that which was so covered at the time of settlement, was in all probability evergreen forest during the later glacial periods, which did not disturb any portion of southeastern Minnesota. In fact it is not unlikely that the

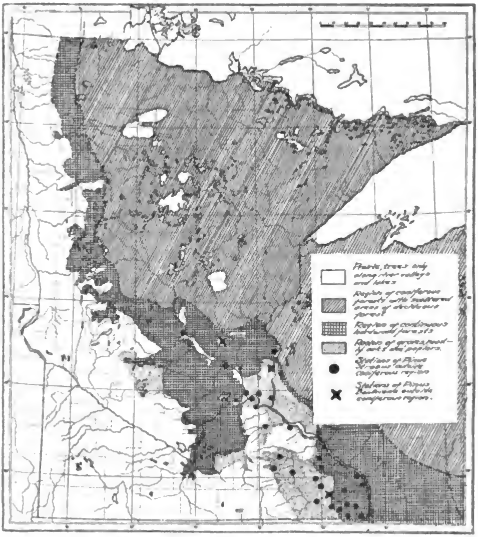
Prairie, trees only along river valleys and lakes
Region of coniferous forests with scattered areas of deciduous forest
Region of continuous hardwood forests
Areas of groves, mostly of oaks and poplars.
Stations of Pinus Strobus outside coniferous region
Stations of Pinus Banksiana outside coniferous region.

Fig. 2. Map showing forest areas of Minnesota

wholly driftless area of Minnesota and the adjoining states harbored such forests throughout all the time that glaciers were sweeping around it, first on one side and then on another. That evergreen forests can exist in close proximity to and even upon glaciers is shown by conditions which now obtain in the Selkirk Mountains and in Alaska.

The subsequent disappearance of most of the pine from southeastern Minnesota and northeastern Iowa can be ascribed to a combination of causes. The gradual warming up of the climate brought about conditions more favorable for the development of deciduous forests and in the competition that ensued the pine gradually lost out. Such competition would be less sharp, and the dangers to the pines from the excessive shade of the deciduous trees less imminent on the ledges and steep slopes where the pines are now found. A factor which undoubtedly played an important part in the elimination of the pine was the repeated entrance of fires from the neighboring prairie country. Even within the wooded region of southeastern Minnesota there are numerous small prairie tracts, especially along the high ridges, and the south-facing hills of the east and west trending river and stream valleys. It is a well known fact that pine trees are much more easily injured and destroyed by running fires than deciduous trees, and the only place where they would have a chance to survive would be on some of the favorable rocky ledges and river bluffs where the fires could not reach them—just the places where the pine now occurs in this region. That fires, such as are known to have been habitually started by the Sioux Indians, had much to do in determining the extent of even the deciduous forests of southeastern Minnesota, is shown by the fact that numerous exposed ridges in Houston and Fillmore Counties are now timbered, which were devoid of trees at the time the country was settled some sixty-five years ago. Since the country became settled and the fire danger thereby was eliminated, numerous artificial groves of white pine have been established throughout the region. Some of the best examples of these groves are located as far west as Austin in Mower County, well out in what is classed as prairie country.

Even though the Jack pine is represented in southeastern Minnesota by but a single known natural grove, our assumption is that it occurred synchronously with the white pine and balsam fir[1] throughout the region in localities suitable for its development, namely on the sandy soils which occur near extensive outcrops of sandstone.

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[1] For a similar isolated occurrence of the latter tree in the adjacent part of northeastern Iowa, see Sargent, C. S., American Sylva, **12**, 109. This locality is believed to be now extinct. According to M. P. Somes the balsam fir occurs also several miles south of Hesper, Iowa.

That no more relics of it occur is to be explained by the theory that fires and competition with deciduous forest trees drove it out of all other localities, for it could not, like the white pine, take refuge on rocky dolomite ledges of the river bluffs, the soils of such places not being favorable for its growth. In the single place where it is still holding out, the soil is too sandy for other native trees to compete with it successfully and moreover fires from the southwest are effectively blocked by high sandstone edges and probably also by the late lying snows of spring on the upper, more abrupt portions of the north-facing hill.

# SOME FACTORS AFFECTING INULASE FORMATION IN ASPERGILLUS NIGER

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## D. EXPERIMENTAL RESULTS

### *a. Preliminary experiments*

The results of numerous preliminary experiments clearly indicate that *Aspergillus niger* grows well on the culture medium above mentioned in which the ordinary carbohydrates are used as the source of carbon. Cultures grown on inulin appeared to be slightly stimulated during the first twenty-four hours of growth and came to full sporulation a few hours before cultures grown on glucose, sucrose or maltose. The dry weight of the mycelium formed at the beginning of sporulation of cultures grown on inulin was generally slightly less than that of cultures grown on equal concentrations of the sugars mentioned. Growth on soluble starch was rather slow and the amount of growth somewhat less than on any of the other carbohydrates, except lactose, which, as Dox (1910) and others have already shown, produces almost no growth unless the fungus is at first started on other media and then transferred to lactose. Tests with Fehling's solution of culture media containing inulin as a source of carbon showed strong reducing power after the fungus had grown for a day. Whether or not reducing sugars are present at the beginning of sporulation appears to depend on the primary concentration of inulin. Up to the point where the amount of inulin present was clearly in excess of what could be rapidly assimilated by the fungus, the dry weight of fungus produced was nearly proportional to the amount of inulin present.

The results of preliminary experiments both with fresh mycelial extracts and with the extracts of the mycelium treated as described above show an abundant hydrolysis when these solutions are added to a solution of inulin. The primary aim in these preliminary experiments was to ascertain whether or not there was a definite stage in the life-history of the organism, at which the greatest amount of enzyme was present in the mycelium. For reasons to be discussed later, it seemed undesirable to attempt to consider any enzymes which the culture medium might contain thus making it especially desirable to have a definite criterion for deciding when the mycelium should be treated. As has been pointed out above, practically all investigators have found that the mycelium contains the greatest amount of enzymes at the beginning of the sporulation period.

The purpose of the first experiment was to determine if possible whether the greatest amount of inulase in the mycelium of *Aspergillus niger* was at the beginning of the period of sporulation or at some other period. Sixty-five cultures each containing 25 cc. of culture medium and 1% of inulin were inoculated and incubated at 30°C. At the end of each of the following periods, thirteen cultures were removed and treated: viz., thirty-two hours, forty-eight hours, seventy-four hours, ninety-six hours, one hundred and twenty hours. 200 cc. of water were added to each gram of the treated mycelium and 50 cc. of the solution of enzymes thus obtained used with each unit of the experiments. As mentioned each unit of an experiment consisted of 250 cc. of solution containing a definite amount of fungal extract and 1 gram of inulin. Digestion was continued at 40°C. for four hours. The data tabulated below show that the greatest hydrolysis of inulin was brought about by extracts from the forty-eight hour cultures, at the end of which time sporulation had just begun. Fungal extract from the thirty-two hour cultures was somewhat less active than that from the forty-eight hour cultures. After the beginning of sporulation the amount of enzyme present in the mycelium fell off rapidly until at the end of a one-hundred and twenty hours the amount of enzymatic activity was almost nil. It thus appears that, when sporulation begins, there occurs a distinct falling off in the inulase content of the mycelium. The following table summarizes the results of the experiment and shows that the greatest amount of enzymatic activity per unit of treated mycelium was at the beginning of the sporulation period.

### *b. Effect of various carbohydrates as the sole source of carbon on inulase formation*

As seen from the review of the literature numerous workers have tested the effects of various carbohydrates on the formation of carbohydrate-splitting enzymes. But few workers have studied inulase from this point of view. The results of Dox (1910) and Boselli (1911) in their studies of inulase are so diametrically opposed that it seemed desirable to perform experiments along a similar line. The first experiment performed was a test of the effects of inulin, soluble starch, and sucrose on the production of inulase in *Aspergillus niger*, when present in the culture medium to the extent of 1%. The fungal extract was prepared by extracting the prepared mycelium with 400 cc. of water per gram of dehydrated mycelium. Equal amounts of the fungal extract and of a 2% inulin solution were mixed giving a solution containing 1% of inulin. This experiment was run for twenty-four hours.

TABLE 1

*Showing the amount of inulase present at different times in the mycelium of Aspergillus niger*[*]

| AGE OF CULTURES WHEN TREATED | PERCENTAGE OF HYDROLYSIS OF INULIN BY EQUAL UNITS OF FUNGAL EXTRACT IN FOUR HOURS |
|---|---|
| *hours* | *per cent* |
| 32 | 25.35 |
| 48 | 27.40 |
| 72 | 20.12 |
| 96 | 5.47 |
| 120 | traces |

[*] All data in this and succeeding tables represent the amount of hydrolysis less hydrolysis of controls.

The results of this experiment show very clearly that, in the presence of inulin, *Aspergillus* produces a greater amount of inulase than in the presence of equal amounts of sucrose or soluble starch. From later experiments it will appear that the amount of hydrolysis brought about by the fungal extracts of inulin and starch cultures is rather low, and since these cultures ran some ten hours beyond the time of full sporulation, it is believed that some of the enzyme may have already been lost. The question as to whether or not starch is more efficient than sucrose in stimulating the production of inulase can best be discussed in connection with data to be presented later. The numerical data of this experiment are presented in tabular form below.

TABLE 2

*Showing the effect of different sources of carbon in 1% concentration on inulase formation*

| FUNGAL PREPARATIONS FROM CULTURES USING SOURCES OF CARBON LISTED BELOW | PERCENTAGE OF HYDROLYSIS OF INULIN BY EQUAL UNITS OF FUNGAL ENZYME PREPARATIONS |
|---|---|
| | *per cent* |
| Inulin | 50.56 |
| Soluble starch | 34.20 |
| Sucrose | 33.94 |

The above experiment deals with substances, all of which require hydrolysis before the fungus is able to utilize them. In order to check up the results already obtained and at the same time compare the effects of substances which require enzyme action with a substance which may be used directly as a source of carbon on inulase formation, the above experiment was repeated and dextrose was used in addition to the carbohydrates already employed. As above described the source of carbon was added to the culture medium in the proportion of 1%. Fourteen cultures for each of the carbohydrates named were run until the beginning of the sporulation period. The results of these experiments are tabulated as follows:

TABLE 3

*Showing the effect of different sources of carbon in 1% concentration on inulase formation*

| FUNGAL PREPARATIONS FROM CULTURES USING SOURCES OF CARBON LISTED BELOW | PERCENTAGE OF HYDROLYSIS OF INULIN BY EQUAL UNITS OF FUNGAL ENZYME PREPARATIONS |
|---|---|
| | *per cent* |
| Inulin | 74.51 |
| Soluble starch | 48.19 |
| Sucrose | 32.78 |
| Glucose | 29.96 |

The results of this experiment show, as does the previous one, that inulin is much more efficient in stimulating inulase formation than any of the other substances used. Soluble starch stands next in order of efficiency, being approximately 65% as efficient as is inulin. Sucrose is much less efficient than starch, while glucose is the least efficient of the four substances tested.

The two experiments just described give tolerably conclusive results regarding the effects of the carbohydrates used on inulase secretion, but in order to check these results still further the experiment was repeated in all of its essential details, with certain minor variations in the methods employed. While all ordinary precautions were observed to prevent bacterial action in experiments on the hydrolysis of inulin by inulase, it seemed probable that in the course of a day or more, even though toluene was used, some bacterial action on the inulin might have taken place. For this reason a third experiment along this line was run for a period of only four hours. With the precautions taken with regard to the sterilization of all glassware, water, etc. it seems highly improbable that even the slightest amount of hydrolysis could have been brought about by bacteria.

As a further check on the accuracy of the above experiment, the sugar analyses were made by Fehling's gravimetric method rather than by the volumetric method previously employed. Since the period of hydrolysis of the zymolyte was rather short, the percentage of hydrolysis was naturally much smaller than before, but this should not alter the comparative relations of the experiment. Besides being grown on inulin, soluble starch, sucrose and glucose, *Aspergillus* was also grown on maltose and as in the previous experiments these substances were employed in the concentration of 1%.

The results of the experiment described in the last paragraph above are strikingly in accord with the results tabulated in table 3. Cultures on inulin show a much greater amount of inulase than do any of the other cultures. As in the previous case starch stood next in efficiency, sucrose and maltose were next in order, while glucose was far less efficient than any of the other carbohydrates employed, as shown before. The numerical results of this experiment are tabulated below. Twenty cultures for each source of carbon were used.

### c. *Effect of varying amounts of inulin, as the sole source of carbon on inulase formation*

It appears from the above described series of experiments that of the substances employed as a source of carbon inulin is the most effective in stimulating inulase formation. The question naturally arises as to whether or not this is an effect which is proportional to the mass of the inulin present or whether it is an effect, which depends upon the contact of the dissolved inulin particles with the organism regardless of their concentration. The first experiment to answer this question consisted in growing *Aspergillus* on media containing as a source of carbon 0.1%, 0.2%, and 0.4% of inulin respectively. The small amount of growth upon all of the cultures and the rapidity with which the carbohydrate disappears indicates that the small amount of inulin present soon becomes the limiting factor in the growth of the fungus. The dry weight of mycelium produced closely parallels the amount of inulin present. From the results obtained it appears that the stimulus for inulase formation is not at all in proportion to the mass of inulin present. The amount of hydrolysis brought about by a definite weight of prepared mycelium from the two sets of cultures containing 0.1% and 0.2% is almost the same. The amount of hydrolysis caused by

TABLE 4

*Showing the effects of various sources of carbon on inulase formation*

| FUNGAL PREPARATIONS FROM CULTURES USING SOURCES OF CARBON LISTED BELOW | PERCENTAGE OF HYDROLYSIS OF INULIN BY EQUAL UNITS OF FUNGAL ENZYME PREPARATIONS |
|---|---|
| | *per cent* |
| Inulin | 11.64 |
| Soluble starch | 7.03 |
| Sucrose | 5.50 |
| Maltose | 5.46 |
| Glucose | 2.49 |

the preparation from the 0.4% cultures although somewhat more than this is not proportionately so. The numerical data for this experiment are presented below. The period of digestion was three hours.

It seemed desirable to repeat the above experiment using greater concentrations of inulin and thus to provide greater actual differences in the amount of inulin present per unit of culture medium. The last experiment was, therefore, repeated using cultures containing 1%, 1.5% and 2% of inulin as the sole source of carbon. The two higher concentrations apparently provide more carbohydrate than can be used in the ordinary life cycle of *Aspergillus* under the conditions of the experiment, since large amounts of carbohydrate remain unused when the sporulation period begins. The results of this experiment are surprisingly uniform. The amount of inulin hydrolysis for equal amounts of treated mycelium does not vary beyond the limits of experimental error.

TABLE 5

*Showing the effect of various concentrations of inulin as the sole source of carbon on inulase formation*

| FUNGAL PREPARATIONS FROM CULTURES USING SOURCES OF CARBON LISTED BELOW | PERCENTAGE OF HYDROLYSIS OF INULIN BY EQUAL UNITS OF FUNGAL ENZYME PREPARATIONS |
|---|---|
| | *per cent* |
| Inulin cultures (0.1%) | 14.21 |
| Inulin cultures (0.2%) | 14.34 |
| Inulin cultures (0.4%) | 16.34 |

Apparently in neither of these last described experiments is the lowest concentration of inulin capable of stimulating inulase formation reached although a decrease in formation begins to be apparent when only 0.2% of inulin is present in the culture medium. Conversely, no increase in inulase production for the higher concentrations of inulin was observed. In connection with some later results, further light on the lower limits of stimulation will appear.

### *d. Effect of inulin on inulase formation in the presence of glucose*

It seems clear from the above mentioned experimental data that inulin is the most efficient substance used as a source of carbon in stimulating inulase formation and also that glucose is the least efficient of the substances used as a source of carbon in stimulating inulase formation. It further appears very probable that glucose is absorbed and assimilated by the fungus without the intervention of enzymatic action. If this be true, glucose should then be much more readily assimilated than inulin and providing that it be present in sufficient quantities to serve as a source of carbon for the fungus, one would expect at least on *a priori* grounds, that glucose would tend to counteract the stimulatory effects of inulin. As will be seen from the literature already reviewed certain investigators have obtained similar results with certain other enzymes.

TABLE 6

*Showing the effect of various concentrations of inulin as the sole source of carbon on inulase formation*

| FUNGAL PREPARATIONS FROM CULTURES USING SOURCES OF CARBON LISTED BELOW | PERCENTAGE OF HYDROLYSIS OF INULIN BY EQUAL UNITS OF FUNGAL ENZYME PREPARATIONS |
|---|---|
| | *per cent* |
| Inulin cultures (1.0%) | 27.39 |
| Inulin cultures (1.5%) | 27.79 |
| Inulin cultures (2.0%) | 26.39 |

In order to test this last hypothesis, the following series of cultures were set up and inoculated with spores of *Aspergillus niger:* viz., series *A* containing 1% of glucose as the sole source of carbon; series *B* containing inulin with a carbon content equivalent to that of the glucose of series *A*; and series *C* having 0.5% of glucose plus inulin which had a carbon content equivalent to 0.5% of glucose. Thus all the cultures contained an equal number of carbon atoms per unit volume. It was found that the two sets of cultures containing inulin are appreciably stimulated at the beginning of the growth period and further that they come to sporulation some 24 hours before the cultures containing only glucose sporulate. The dry weight of fungus produced, however, is greatest in series *A*. The dry weight of the cultures of series *B* is least while the dry weight of series *C* is intermediate between the other two. Tests of the hydrolytic power of the enzyme produced by the fungus in each of the three series of cultures reveal no difference whatever between the activity of the enzyme from series *B* and *C*, both of which contained inulin, while the amount of hydrolysis from the enzyme of series *A* is only a little more than one-fourth as great as that caused by the enzyme from series *A* and *B*. The results of this experiment show in a very striking manner that glucose has little influence on inulase formation in the concentration used, when inulin is present in equal concentration of carbon atoms. Further, the results for cultures containing only inulin or glucose parallel very closely the results tabulated in tables 2, 3 and 4. The following table shows that glucose is without effect on inulase formation in the presence of inulin in the amounts used.

TABLE 7

*Showing the effect of inulin on inulase formation when in the presence of glucose*

| FUNGAL PREPARATIONS FROM CULTURES USING SOURCES OF CARBON LISTED BELOW | PERCENTAGE OF HYDROLYSIS OF INULIN BY EQUAL UNITS OF FUNGAL ENZYME PREPARATIONS. |
|---|---|
| | *per cent* |
| Series *A* (Glucose 1%) | 7.1 |
| Series *B* (Glucose 0.5% + inulin 0.5%) | 27.29 |
| Series *C* (Inulin 1%) | 27.18 |

A second experiment of the same nature as the above corroborates the results of this experiment and also throws light on the lower limits of efficiency of inulin as a stimulus to inulase formation. The essential details of this experiment are described below.

Cultures were set up as in the previous experiment, according to the equivalent carbon concentration in the following series: viz., series *A* containing 2% of glucose alone; series *B* containing 1.9% of glucose and inulin, equivalent in carbon content to 0.1% of glucose; series *C* containing 1% of glucose and inulin equivalent in carbon content to 1% of glucose; series *D* containing 0.1% of glucose and inulin equivalent in carbon content to 1.9% of glucose; and series *E* containing inulin only, equal in carbon content to 2% of glucose. The results of this experiment parallel very closely the results set forth in table 7. If inulin is present in concentrations of about 1% or more, very little decrease in inulase formation is observable due to the presence of glucose. The slight decrease in the results from series *E* to series *C* may be due to a decrease in the amount of inulin present. However, the results of series *A* and *B* show that 0.1% of inulin is below the limit of efficiency of inulin as a stimulus to inulase production and that somewhere between 0.1% and 1% one would expect to find a point where the stimulatory effect of inulin first becomes apparent. The numerical data for the last experiment are presented above. The time of digestion was four hours.[1]

TABLE 8

*Showing the effect of inulin in the presence of glucose on inulase formation*

| FUNGAL PREPARATIONS FROM CULTURES USING SOURCES OF CARBON LISTED BELOW | PERCENTAGE OF HYDROLYSIS OF INULIN BY EQUAL UNITS OF FUNGAL ENZYME PREPARATIONS |
|---|---|
| | *per cent* |
| Series *A* (Glucose 2%) | 25.27 |
| Series *B* (Glucose 1.9% + inulin 0.1%) | 20.48 |
| Series *C* (Glucose 1% + inulin 1%) | 93.09 |
| Series *D* (Glucose 0.1% + inulin 1.9%) | 95.92 |
| Series *E* (Inulin 2%) | [illegible] |

## E. DISCUSSION AND THEORETICAL CONSIDERATIONS

As stated above, the purpose of this investigation has been to demonstrate in a quantitative as well as a qualitative way the formation of an enzyme in a living organism. The choice of inulase, as to the enzyme to be studied, presented both advantages and disadvantages. Inulin itself has been little studied and its chemical formula, although better established than that of starch, has not been placed on a firm basis. Neither have the analytical methods for the determination of inulin or of fructose in the presence of inulin been placed on an entirely satisfactory basis. However, analytical methods have proved to be sufficiently accurate to allow comparative studies, which have given reasonably uniform results. Inulin is much more soluble than starch and can be employed in fairly concentrated solutions with the assurance that solutions are of uniform strength. Again, the similarity between the structure of inulin and that of starch makes a comparison of their corresponding enzymes of real value. In addition to these considerations, inulase has been little studied from the point of view of its regulatory secretion, and the existing data of this nature seem highly contradictory in character.

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[1] The concentration of all the fungal extracts used in this experiment was considerably greater than that used in previous experiments, which accounts for the relatively great amount of hydrolysis in four hours.

Dox (1910) and Boselli (1911) have arrived at very different conclusions in regard to the quantitative regulation of inulase by fungi, as noted in the review of the literature; and in selecting the method of attacking the problem it seems best, therefore, to compare their methods and results with a view to determining whose results are more likely to be correct. The main factors in experiments of this nature are the methods of growing the fungus and the methods of securing and employing the enzymes produced. There appears to be no essential difference in the methods of growing the fungus, but in the methods of using the enzyme produced, one finds that there is much difference. Dox has employed the mycelium only, treating it at the beginning of the sporulating period according to the well known "acetone daurhefe" method. Boselli, on the other hand, has attempted to study the combined activities of the enzymes of the culture medium and the enzymes as extracted directly from the mycelium. Theoretically this appears to be the ideal method of experimentation, accounting as it does for all of the enzyme that has been produced and also employing the enzyme directly without precipitation, which has been repeatedly shown to lower the activity of the enzyme. Practically, however, this latter method does not lend itself to quantitative methods of study, since too many uncontrolled factors are introduced. It is very difficult to estimate the amount of mycelium used in experiments, if the fresh mycelium is used directly, but, if it is dehydrated by means of such substances as alcohol, acetone, or ether, the dry weight of the fungus is a fairly accurate index of the actual comparative number of cells present in different amounts of mycelium. This allows a comparative study of different cultures. The use of ether, acetone, etc., in this method removes many substances such as certain lipoids, etc., which would be present as foreign substances in a fresh mycelial extract. There are many other advantages, which make this method more convenient to use, but which need not be discussed here. With regard to the use of enzymes, which have been excreted into the culture medium, it seems apparent that it is impossible to control the nature of the substances with which the enzyme is in contact and, for this reason it is impossible to compare the activity of various enzyme solutions under such conditions. Furthermore, if only the original salts and carbohydrates of the culture medium were present in their original concentrations, which is manifestly not the case, it would be very difficult to compare the activity of enzymes acting under such conditions with the activity of enzymes derived directly from the mycelium. It, therefore, seemed more desirable to employ methods similar to those of Dox rather than those of Boselli, whose results are quite at variance with those usually obtained in experiments of this nature. For similar reasons, no attempt was made to estimate the amount of enzyme produced based on the rate of disappearance of the carbohydrate from the culture medium, as has been done by certain other investigators.

It has been shown from the work of previous investigators that in general the period of greatest enzyme content in the fungi is just at the beginning of sporulation, and these experiments show that this is also true with regard to the inulase content of *Aspergillus niger*. For this reason the enzyme preparations used have been prepared from the mycelium at this stage of its life cycle.

As has been already suggested, studies of enzyme regulation are grouped around the idea of either a qualitative or a quantitative regulation. Early investigators who worked in this field were prone to look for qualitative enzyme regulation in the fungi. The great ease, with which various forms like *Penicillium* and *Aspergillus* have been found to adapt themselves to growth on almost any organic substance, suggests that these fungi must be able to produce enzymes acting on any of these substances as occasion arises. It is not surprising then that, with the more or less imperfect methods at hand and with the use of such obscure forms as "*Penicillium glaucum,*" which has served as a vehicle for so many of these studies, many investigators believed that they had found cases of qualitative enzyme regulation. Many of these results appear to be due to the employment of chemical methods, which were not accurate enough to detect enzymatic action in slight amounts, while other results are clearly invalidated by the use of mixed cultures of unidentified or obscure organisms. Even so recent an investigator as Kylin (1914) employs "*Penicillium glaucum*" in certain experiments. It is now well known that *Penicillium glaucum* is no more distinctive as a fungus than "green mould" and as Dox has suggested, the various forms of *Penicillium* formerly grouped under this name are so varied in their physiological reactions as to invalidate any comparisons, based on species of *Penicillium* which were not more definitely identified.

Recent studies of qualitative enzyme regulation fail to reveal more than one well authenticated case of qualitative enzyme regulation. As has been suggested above, the work of Knudson (1913) seems to leave little doubt that there exists a qualitative regulation of tannase formation. It appears to be quite generally the impression of those authors, who have reviewed Knudson's work, that it was carefully done and that his results are entirely dependable.

The results of the experiments above described show very clearly that there is no qualitative regulation of inulase formation in *Aspergillus niger*. Inulase is always produced in sufficient quantities to be easily demonstrable. It should be said, however, that the conditions under which the fungus was grown were extremely limited, since only the common carbohydrates were used as a source of carbon. It is not at all improbable that the use of proteins, organic acids, alcohols, etc., as the source of carbon might give entirely different results and, at least, it is to be expected that some of these substances would be less efficient in stimulating inulase formation than were any of the substances employed in this work. The results of Went (1901) in his studies of *invertase* and of Kylin with *maltase*, etc., render it highly improbable, that any qualitative regulation of inulase formation could be found. These investigators employ a great variety of substances including peptone, organic acids and polyhydric alcohols as the source of carbon and find that the enzymes mentioned are secreted under all conditions.

The quantitative regulation of enzymes has been long known and is a firmly established fact so far as the fungi are concerned. It seems to be quite generally the case that the amount of any enzyme produced may vary widely according to the environment of the fungus. Certain investigators have found that enzyme formation can be greatly inhibited by growing the fungus at low temperatures. Kostyschew (1907) and others have shown that appreciable amounts of a zymase-like enzyme are produced by certain fungi and the work of Junitzky (1907) shows that in this case there is an increased enzyme production due to lack of oxygen, since his results show that these fungi produce this same enzyme in small amounts under ordinary conditions.

It has been shown by several investigators that the effect of certain inorganic salts is to increase or decrease enzyme production. As mentioned before Herissey (1899) finds that the presence of large amounts of ammonium nitrate in the culture medium entirely inhibits the formation of emulsin in certain fungi. In the light of the more recent work on enzyme regulation, it seems more than likely that emulsin formation is not entirely suppressed in this case. It seems possible from the results of several French investigators, that the stimulating effects of such a substance as zinc, may perhaps be related to its effect on enzyme production.

Organic food material is the most commonly recognized factor in the stimulation of enzyme production. The numerous results which all show that various organic sources of nitrogen and particularly of carbon vary greatly in their power of stimulating enzyme production have already been reviewed. It is commonly recognized that the carbohydrate or other substance corresponding to a particular enzyme causes that enzyme to be produced in much larger quantities than do other substances. However, not all investigators have found such a stimulatory relation existing between the substance and its correspondingenzyme. Katz (1898) finds that starch alone is not so effective in stimulating diastase production as when other substances more readily assimilated are present in addition to it. Boselli (1911) finds that all of the substances, which he employed as the source of carbon, are equally efficient in stimulating inulase production. His results are strikingly at variance with the results of Dox and with those described in this work. While in no case has there been shown such a striking response to the stimulatory effects of inulin as there was in the experiments of Dox, still without any exception inulin is found to be much more efficient than any of the other substances used. As has been suggested before, the methods employed by Boselli (1911) are open to serious criticisms and his results, for this reason, do not appear to be reliable.

Not only do many organic foods have the power of causing an increase in the amount of their corresponding enzymes over and above what is produced under other conditions of nutrition, but to a cerain extent, at least, the amount of enzyme produced appears to depend on the amount of the zymolyte present. As stated before, Went (1901) found that within certain limits many substances cause an increase in the formation of their corresponding enzymes when they themselves are increased. This increase is not proportional to the amount of increase of the zymolyte but is considerably less. Knudson (1913) has also shown in connection with his studies of tannase that increased amounts of tannic acid stimulate the secretion of increased amounts of tannase. The results obtained in the experiments herein described indicate that a similar result may be brought about with relation to inulase. Within very restricted limits an increase in the amount of inulin present causes an increase in the amount of inulase formed. Thus, as is shown in table 5, 0.1% and 0.2% of inulin in the culture medium results in equal inulase production, but an increase to 0.4% of inulin results in a slight increase in inulase production, which is by no means double the production in the first two cases. Again in table 8 it will be seen that 0.1% inulin in the presence of 1.9% glucose has no effect beyond the enzyme production with glucose alone. Evidently, under the conditions of these two experiments, 0.2% of inulin is below the minimum for the stimulatory effect of this substance, while 0.4% is somewhat above it. The results shown in table 6 reveal the fact that, between the effects of 1%, 1.5%, and 2% solutions of inulin, there is no significant difference so far as the stimulation of inulase production goes. These concentrations are evidently all above the maximum strength which will cause increase in inulase production. The maximum and minimum points for the stimulation of inulase production by inulin seem to lie between 0.4% and 1%. It must be said, however, that it would be very desirable to have a much greater amount of data on this point than is presented in this work. That such an increase of inulase production exists and that it lies within rather narrow limits is undoubtedly the fact, but more data are needed to establish these points more definitely.

Many investigators believe enzyme production to be a "hunger phenomenon," while others have found that enzymes are produced more abundantly under more favorable conditions of nutrition. On theoretical grounds, one might expect the former to be true. Evidently, however, one must discriminate between at least two phases of "hunger." If an organism is in the presence of only a limited amount of food material, its growth will be limited by the amount of food present. Some investigators have found that under such conditions the fungus will increase its production of enzymes. Herissey (1899) and Brunstein (1901) find that the production of emulsin appears to be a starvation phenomenon. The former has found that mycelium, which contains no emulsin, can be made to produce it when starved on pure water. In view of the fact that the presence of the zymolyte has been shown to result in an increased enzyme production, it seems probable that enzyme production is a direct result of chemical stimuli and it is difficult to understand how the absence of stimulatory agents can have the same effect as their presence.

Other investigators have apparently considered *the presence of substances,* which are acted upon by digestive enzymes only with difficulty, as being a *starvation phenomenon.* Thus the increased production of diastase under conditions, when only starch is present as the source of carbon has been considered by such investigators as a hunger phenomenon, since they also find that diastase production is more or less inhibited if such substances as sucrose or glucose be present in addition to starch. Clearly this condition is very different from the condition of starvation first mentioned: *i.e.,* the entire absence of food substances. It is entirely unnecessary to consider enzyme formation in this second case as a hunger phenomenon since evidently the contact of the zymolyte with the organism is the stimulatory agent which affects enzyme production.

The results of the present study on the regulatory formation of inulase would indicate that stimulation to increased production depends upon a direct chemical stimulus due to substances present in the culture medium. Inulin is the most efficient of the substances used in stimulating inulase production. An increase in the amount of inulin present causes an increase of inulase production rather than a decrease, and very small amounts of inulin are unable to increase inulase production. The results also show that the stimulatory effects of inulin are independent of the presence of glucose, which supposedly is a more easily assimilated substance than inulin. The results shown in tables 7 and 8 indicate that, if inulin is present in sufficient amounts to stimulate inulase production, the presence of glucose in equal amounts has no influence on inulase production. If the stimulatory effect of inulin is due to some relation of the dissolved particles to the plasma membrane of the organism or to some similar stimulation, then glucose would not be expected to have an inhibitory effect unless we conceive of some "antagonistic" relation between the particles of the two substances, for which antagonism there is at present no evidence. Evidently in the case of inulase, at least, under the conditions of these experiments, the production of the enzyme is not a starvation phenomenon, but quite the reverse and further, its production appears to be quite independent of the presence of glucose which, although causing an increased growth of the fungus, does not affect the amount of inulase produced.

Previous investigators do not appear to have considered, to any extent, the fact that closely related substances are more effective in stimulating the enzymes corresponding to the related substances than are less closely related substances. Knudson (1913) has shown that gallic acid in addition to tannic acid is able to stimulate tannase production. The results here presented indicate that soluble starch is much more effective in stimulating inulase production than glucose. It seems probable, that the preliminary steps in enzyme production may be more or less common for a number of enzymes and that the changes which finally produce enzymes, affecting closely related substances, may be sufficiently alike to be affected to some extent by closely related substances in the substratum. The results obtained by Pottevin (1903) on the effect of the space relations of various carbohydrates on the enzymes produced by fungi suggests that a study of the effects of fructose and its derivatives and of other hexose sugars might be of interest in relation to inulase production.

## F. SUMMARY OF RESULTS

1. Under all conditions studied inulase is produced by *Aspergillus niger* in appreciable quantities.

2. Inulase is present in the fungus mycelium in greatest amounts at the period of sporulation of the fungus and rapidly disappears after that time.

3. Inulase is produced in greater amounts by the fungus, when inulin is present in the culture medium, but is also formed when other carbohydrates are used as the sole source of carbon.

4. After inulin, soluble starch is the most efficient of the substances used, in the stimulation of inulase formation, while glucose is least efficient.

5. Substances which are more nearly related in their chemical structure appear to be more efficient in stimulating enzyme formation than are substances not closely related.

6. The production of inulase may be increased or decreased within certain limits by changing the amount of inulin in the culture medium, but this effect is by no means proportional to the increase or decrease in the amount of inulin.

7. Glucose in the presence of inulin appears to be without effect on inulase production.

8. The production of inulase does not appear to be in any way a starvation phenomenon.

## G. BIBLIOGRAPHY

Bartholomew, E. T.: Concerning the presence of diastase in certain red algae. Bot. Gaz., **57**: 136–147, 1914.

Boselli, J.: Étude de l'inulase, d'*Aspergillus niger*. Ann. de l'Institute Pasteur, **25**: 695–704, 1911.

Brunstein, A.: Ueber Spaltungen von Glycosiden durch Schimmelpilze. Beih. Bot. Centbl., **10**: 1–50, 1901.

Colin, H.: Hydrolyse de quelques polysaccharides par le *Botrytis cinerea*. Thèse Paris, 1911.

Dox, A.: The intracellular enzyms of Penicillium and Aspergillus, etc. U. S. Dept. of Ag., Bu. of Animal Ind., Bul. 120, 1910.

Duclaux, E.: Traité de Microbiologie, 2, Paris, 1899.

Fernbach, A.: Recherches sur la sucrase, diastase inversive du sucre de canne. Thèse de doctorat, Paris, 1890.

Green, J. R.: On the germination of the Jerusalem artichoke (*Helianthus tuberosus*). Ann. of Bot., **1**: 233 (1888).

Haas, P. and Hill, T. G.: The Chemistry of Plant Products, First Ed., London, 1913.

Herissey, H.: Recherches sur l'Emulsine. Thèse, Paris, 1899.

Iwanoff, L.: Ueber die fermentative Zersetzung der Thymonucleinsäure durch Schimmelpilze. Ztschr. f. physiol. Chemie., **39**: 31–43, 1903.

Junitzky, N.: Ueber Zymase aus *Aspergillus niger*. Ber. der deut. Bot. Ges., **25**: 210–213, 1907.

Katz, J.: Die regulatorische Bildung von Diastase durch Pilze. Jahrb. f. wiss. Bot., **31**: 599–618, 1898.

Knudson, L.: Tannic acid fermentation, Parts I and II. Jour. Biol. Chem., **14**: 159–202, 1913.

KOSTYTSCHEW, S.: Ueber die Alkoholgärung von *Aspergillus niger*. Ber. der. deut. Bot. Ges., **25**: 44–50, 1907.

KYLIN, R.: Über Enzymbildung und Enzymregulation bei einigen Schmimelpilzen. Jahrb. f. wiss. Bot., **53**: 465–501, 1914.

POTTEVIN, H.: La tannase. Diastase dédoublant l'acide gallotannique. Compt. Rend., **131**: 1215–17, 1901.

POTTEVIN, H.: Influence de la configuration stereochimique des glucosides sur l'activité des diastase hydrolytiques. Ann. de l'Inst. Pasteur, **17**: 31–51, 1903.

WENT, F.: Über den Einfluss der Nahrung auf die Enzymbildung durch *Monilia sitophila* (Mont.) Sacc. Jahrb. f. wiss. Bot., **36**: 610–664, 1901.

# BOOKS AND CURRENT LITERATURE

FORESTRY OF THE NORTHEASTERN STATES.—The authors of Forestry in New England" (John Wiley & Sons: 1912) have brought out a revised edition[1] of that portion of their earlier work that surveys the field of forestry and sets forth the fundamental principles on which rest the practice of forestry as an art. This work forms the first volume of a manual the second volume of which will deal with New England forests and their management, but it is unlikely that that volume will appear until the conclusion of the war.

From long practical experience both in teaching and in state forestry work, the authors are well fitted for their task. For use in colleges and by the general reader Forestry in New England has held a well merited place in American forest literature. In its new dress the matter presented can be put to still more extended use, for its clear statement of principles, in convenient and compact form, entitles this book to a much wider field than the portions of New York, New Jersey, Pennsylvania and Southeastern Canada, where the forest conditions approximate those of New England. Especially will this volume be of value in the agricultural colleges and other schools that without attempting to give professional training, yet offer general instruction in forestry.

In the main the present volume covers the topics treated in Part I of the first edition. But the arrangement has been improved and given more logical sequence. One notable feature, for which the authors are to be commended, is that they have consistently followed throughout the revised terminology proposed by a Committee of the Society of American Foresters in 1916.[2]

The introductory chapter discusses briefly the basic principles underlying silvics of forest ecology. This is followed by a statement of the silvicultural characteristics of some 24 New England trees, considerably augmented over the first edition by data taken from recent Forest Service bulletins, state reports and other sources. Then come descriptions of the silvicultural methods of reproducing forests, forest planting and seeding and intermediate cuttings. In the discussion of injuries to the forest from animals, insects, fungi and forest fires not unnaturally somewhat more full notice is given to the white pine blister rust and to the chestnut bark disease. Two forest insects not mentioned in the first edition are briefly described—the European pine-shoot moth (*Evetria buoliana*) and the pine sawfly (*Diprion simile*). The three final chapters are on timber estimating and marketing, utilization of forest products and growth of trees and forests. In the rearrangement the chapter on growth might well have preceded that on estimating. That on utilization is all new matter and rounds out the volume in a desirable way, especially where it is to be used as a text book.

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[1] Hawley, Ralph C., and Hawes, Austin, F. Manual of Forestry for the Northeastern United States. Pp. xii + 281, illustrated. New York, John Wiley and Sons ($2.00).

[2] "Forest Terminology," Journal of Forestry—Vol. XV, No. 1, pp. 68–101. Washington, D. C., January, 1917. See also Vol. XVI—No. 1, pp. 1–75. January, 1918.

Another improvement in the new edition is the inclusion in the appendix of a much larger number of tables than appeared originally; 80 as against 56. It is no small convenience to foresters to have such data assembled in one place, the more so as some of the tables here reprinted are not otherwise readily accessible. The tables include log rules, volume tables, growth figures for individual trees, and yield tables. The authors state their aim to be "to gather together all the reliable tables at present available, which contain figures showing volume and growth for the important commercial trees and types," but as they point out "the field is very incompletely covered and indeed for many species data are entirely lacking;"—an interesting commentary that forestry in this country is still a young profession. Nine of the tables are original with the authors, as against two in the first edition, but of these all have previously appeared in reports or bulletins issued either in Connecticut or Vermont.

The manual is illustrated with the plates and diagrams used in the first edition. Special mention may be made of the diagrams, in that they clearly bring out the esssential differences between the several silvicultural methods, a point that particularly needs to be emphasized since many persons appear to feel that forestry practice consists solely in the leaving of a few seed trees and the fixing of a diameter limit. The make-up of the book is what we have come to expect in Wiley's forestry series, both paper and press work being of a high standard. No mistake can be made in putting this volume on one's shelf of forestry books.—R. S. HOSMER.

THE ALGAL AND BACTERIAL FLORA OF JAPANESE WATER SYSTEMS.—Hattori's recently published investigations[1] on the water systems of Japan," although written largely from the standpoint of the sanitary engineer, really constitutes a valuable contribution to ecology. The writer had in view the influence of rainfall, temperature, soil and water content on the nature of the flora of filter beds, as well as on the character of the water. An introductory chapter briefly outlines the development of the Japanese water systems.

The first water system of Japan was planned about 1590 for the city of Yedo, now Tokyo. This system was followed by six others of which the Tamagawa alone finally remained. This consisted of an open canal 52 kilometers in length, reaching from a dam in the Tama River to the city of Yedo where it discharged its flow without filtration into wooden pipes. At present over 70 systems are in operation or building in Japan. Most of these utilize rivers as the source and make use of the sand filtration method.

The efficiency of the sand filter is greatly increased by the slime covering of the sand bed which is formed by a growth of bacteria, blue-green algae, green algae and diatoms. Seasonal variations occur in the flora of this slime coat. In Tokyo, *Microneis* and *Navicula* dominated the algal flora in June, with *Merismopedia*, *Ceratoneis*, *Fragilaria*, *Melosira*, *Cosmarium*, *Pediastrum* and *Mougeotia* abundant. *Spirogyra* was dominant in the Nagasaki filter in August, and *Coelosphaerium* in September and October. In Kobe, *Anabæna*, *Conferva* and *Oedogonium* dominated in July, and *Melosira* in August and September. In Yokohama, *Melosira* was apparently independent of climatic influence, being present throughout the year, but other species of diatoms were seasonal. As a general thing diatoms were first and conjugates second in dominance in the algal flora of the water systems investigated. Fungi such as *Penicillium*, *Aspergillus*, *Mucor* and *Verticillium* were also found, and numerous species of bacteria were identified. In general bacteria were more numerous in summer than in winter, but in some cases there was a tendency to increase in January and February at the time of greatest cold, due to pollution of water sources by dry earth particles rich in bacteria. Also in March and April an increased bacterial count occurred in systems whose sources were subject to washings from melted snow.

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[1] Hattori, H., Mikrobiologische Untersuchungen über einige japanische Wasserleitungen. Jour. Coll. of Sci., Imperial University of Tokyo. Vol. 40, Art. 4. 1917.

One of the much-discussed questions arising in the study of the filter bed flora is the physiological influence of green algae on the development of bacteria. It has been suggested that the oxygen liberated by them during photosynthesis may exercise a retarding effect on bacterial growth. Decrease in nutritive supply in water due to algal activity has also been advanced as a retarding influence. Hattori states that in his investigations there were evident no such physiological connections between algal and bacterial flora. The absence of organic material in the filtered water appeared to be one of the greatest factors concerned in lowering the bacterial count.

Numerous tables are included in the paper setting forth the chemical reaction and constituents of the water supplied to twelve Japanese cities, the efficiency of their water systems as shown by bacterial count of filtered and unfiltered water, the species of algae and bacteria found during different months of the years of investigation, together with weather conditions and other valuable data. There are also illustrations of numerous species of algae and diatoms.—J. G. Brown.

# NOTES AND COMMENT

President Wilson has issued a proclamation establishing three new National Forests in the eastern states, as an outcome of the law passed in 1911 authorizing the acquisition of lands about the headwaters of the principal rivers of New England and the southern Appalachian region. The White Mountain National Forest is located in Grafton, Carroll, and Coos counties, New Hampshire, and in Oxford County, Maine. The areas which have been purchased or approved for purchase aggregate 391,000 acres, lying at the headwaters of the Androscoggin, Saco and Connecticut rivers. The Shenandoah National Forest is situated in Rockingham, Augusta, Bath, and Highland counties, Virginia, and Pendleton County, West Virginia. In this tract 165,000 acres have been brought under federal protection, chiefly in the drainage basin of the Shenandoah River. The Natural Bridge National Forest is situated in Rockingham, Nelson, Amherst, Botetourt, and Bedford counties, Virginia, comprising 102,000 acres. This forest protects a portion of the headwaters of the James River, but does not include the Natural Bridge, which lies near its boundaries in Rockbridge County. These three National Forests aggregate a little more than 1000 square miles, and constitute a very substantial addition to the protected forest areas of the country.

Through an error in the compilation of the list of Doctorates in Botany, published in the March issue, Harvard University was credited with only the two degrees conferred at the mid-year commencement. At the close of the academic year the following degrees were conferred, increasing the number from two to nine.

PH.D.

FREDERIC KING BUTTERS. Studies in the geographical relations of plants of the Selkirk Mountains.

CARL CHESWELL FORSAITH. A report on some Allocthonous peat deposits of Florida.

ALBERT RICHARD CARL HAAS. Studies of plant metabolism in relation to hydrogen ion concentration.

CARL SHERMAN HOAR. The anatomy and phylogentic position of the Betulaceae.

**Harold St. John.** A report on a Botanical exploration of the south shore of the Labrador Peninsula, Saguenay County, Quebec, including an annotated list of the species of vascular plants.

**Frank Jason Smiley.** A report upon the boreal flora of the Sierra Nevada Mountains of California.

S.D.

**George Fouche Freeman.** The heredity of quantitative characters in wheat.

Haas and Hill have prepared a second edition of their Introduction to the Chemistry of Plant Products, (Longmans, $3.50) the first edition of which appeared in 1913. The principal change that has been made is in the re-writing of the section on plant pigments.

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# A COLLOIDAL HYPOTHESIS OF PROTOPLASMIC PERMEABILITY

E. E. FREE

*United States Army*

It is generally agreed that protoplasm is of colloidal nature and that the phenomena of permeability are connected with alterations of some kind in the colloidal state of the surface layer of the cell. During 1916 two investigators have published hypotheses concerning the mechanism by which these changes are brought about. Spaeth[1] assumes changes in the degree of dispersion of the colloids of the surface film. Clowes[2] postulates phase inversions by which, for instance, an emulsoid consisting of non-aqueous globules suspended in an aqueous medium, becomes one of the aqueous globules in a non-aqueous medium, the internal phase becoming the external and vice versa. I shall return later to the critical examination of these hypotheses. First, I shall outline a third hypothesis as to the mechanism of the changes, which hypothesis it is the purpose of this paper to present. This hypothesis occurred independently to Prof. F. E. Lloyd and me in 1914. It has been noted briefly in a publication by Lloyd.[3]

The most important facts which must be explained by any theory of protoplasmic permeability are those of *change* of permeability. Not only are there marked differences between different masses of protoplasm, but the same cell may change in permeability either in response to alteration of external conditions or as the result of internal changes which may be, and frequently are, functional and normal. As examples of changes due

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[1] Science **43**: 502-509 (1916).

[2] Science **43**: 750–757 (1916); Jour. of Physical Chemistry **20**: 407–450 (1916).

[3] Rept. Dept. Botanical Research, Carnegie Inst. of Wash. Year Book, **14**: 68 (1915).

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to external agents one may recall the experiments of Szües[4] on the increases and decreases of permeability caused, respectively, by hydrogen peroxide and by aluminium salts, and the well known work of Osterhout[5] on the antagonistic effects of sodium and calcium salts on the penetration of each other into tissues of *Laminaria*. Instances of normal functional changes of permeability are the increased permeability of muscle cells during excitation[6] and of egg cells after fertilization. All of these changes, whether spontaneous or due to external agents, may be reversible and without apparent injury to the life processes of the cell. Other similar examples are noted in the recent summaries of Höber[7] and Bayliss.[8] A further case which is apparently an example of variable permeability is the fact that cells are usually relatively impermeable to the salts, sugars and amino acids which form the building materials of protoplasm. It is reasonable to assume occasional changes of permeability such as would permit these substances to enter more readily.

It is very probable that the protoplasmic colloids are of the emulsoid type, that is, that they consist of two (or more) liquid phases. A number of simpler colloids of this type have two liquid phases which differ in composition only in the relative proportion of water and of the substance of the colloid.[9] Thus a gelatine sol is believed to consist of globules containing relatively more gelatine, suspended in a medium which contains relatively less gelatine. The medium may be thought of as a more dilute gelatine solution; the globules as a more concentrated one. At greater total concentrations of gelatine this condition may be reversed, the more dilute solution becoming the globule or internal phase; the more concentrated solution, the continuous or external phase. Such systems are stiff gels. In either case, whether the dilute phase act as medium or as globules, it is obvious that the physical properties of the system will be altered markedly simply by the passage of water from one phase to the other. In other words anything which changes the *distribution of water* between the phases will greatly affect the properties of the material. In sols and gels of gelatine and other simple emulsoids this distribution of water is known to be affected by temperature, the presence of salts and other dissolved substances, and even by mechanical stress. All of these things affect the viscosity and other physical properties of the colloid, sometimes in large degree.

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[4] Jahrb. wiss. Bot. **52**: 269 (1913).

[5] Science **36**: 350–352 (1912), Bot. Gaz. **59**: 242–253 (1915).

[6] McClendon, Amer. Jour. Physiol. **29**: 302–305 (1912).

[7] Physikalische Chemie der Zelle und der Gewebe, fourth edition, 1914, especially chapters 8, 10 and 13.

[8] Principles of General Physiology, 1915, chapters 5, 12 and 18.

[9] van Bemmelen, Zeits. Anorg. Chem. **18**: 14–38 (1898), Hardy, Jour. Phys. Chem. **4**: 254–273 (1900); Garrett, Phil. Mag. (6) **6**: 374–378 (1903); Freundlich, Kapillarchemie, 1909, pp. 395–398; Hatschek, Introduction to Physics and Chem. of Colloids, 1913, pp. 43, 46, 59; Scarpa, Koll. Zeits. **15**: 8–10 (1914), Bayliss, *loc. cit.*, pp. 96–99.

It seems not improbable that a similar state of affairs exists in protoplasm, that two (at least) of the liquid phases of protoplasm differ importantly only in the proportions of water which they contain, and that the distribution of the water between these two phases may alter without death of the protoplasm. Such changes in the distribution of the water would explain the known facts of permeability more simply than any hypothesis with which I am acquainted. But ability to explain the facts is only part of the duty of an hypothesis. This suggestion is not intended as a "theory" of permeability or as more than a provisional way of viewing the facts; a way which may prove to contain a part of what is probably a very complex truth.

The comparison of this hypothesis with the facts and with other hypotheses will be facilitated by a picture of the conditions in a protoplasm having the structure which is postulated. Two phases are important; the liquid globules and the liquid medium in which they are suspended. Both are to be imagined as intimate mixtures, perhaps solutions, of some colloid-forming substance with water. Doubtless real protoplasm contains several other phases, solid and liquid, and doubtless the mixtures which form the two phases important to this hypothesis are not really simple solutions of a simple substance. For purposes of explanation these complexities may be disregarded. Considering the two phases mentioned, it is obvious that the globules of the internal, discontinuous phase will be near together or far apart according to the relative volume of the two phases; that is, accordingly to the size and number of the globules relative to the value of the medium in which they are suspended. But this ratio of the volumes of the two phases depends upon the distribution of the water between them. If water passes out of the globules into the medium there will be an increased volume of the medium (external phase) and a decreased volume of the globules (internal phase). If water passes in the reverse direction the total volume of the globules will increase and that of the medium will decrease. If the number of globules remains the same this may be expressed in terms of size. When water passes from medium to globules the globules swell; when it passes in the reverse direction, they shrink. Of course there are corresponding changes in the distances between globules or, what is the same thing, in the average thickness of the layers of medium between them. It is possible to imagine the globules so large that they are packed closely together to the point of mutual deformation, the medium being reduced to a system of thin films between the swollen globules. This condition appears to be realized in many gels. On the other hand, it is possible to imagine the globules so small that they are far apart and touch but seldom, as in most emulsoid sols.

The bearing of these considerations on permeability will be apparent if these changes are imagined as taking place in the surface layer of protoplasm. It may be remarked, however, that the reasoning holds equally well for any protoplasm in any part of the cell and does not depend on the assumption of a differentiated surface layer or Plasmahaut. Considering the surface layer of the cell, whether differentiated or not and regarding it as a two-phase system of the kind described, it is obvious that when the globules of the internal phase are small there will be wide spaces of medium between them. At such times substances soluble in the medium will enter the cell readily. On the other hand when the globules are large the spaces between them will be small, perhaps reduced to mere films, and substances soluble in the medium cannot enter, or will enter only with difficulty. Manifestly, shrinkage or swelling of the globules will affect greatly the ease of entry of substances soluble in the medium. Such shrinkage or swelling will follow changes in the distribution of water between the phases, and, if protoplasm is analogous to simpler colloids, such alterations of water distribution can be caused by changes in electrolyte concentration or by other quite possible causes. No further detail is needed to indicate the possibility of causing by such a mechanism the changes of permeability which are actually observed.

It should be noted that solubility in the globule phase alone will not enable entry into the cell. The globules are isolated. In order to pass from one globule to another a dissolved substance must pass through a layer of medium. No substance can do this unless it is soluble in the medium phase as well as in the globule phase. It follows that a substance which always penetrates readily must do so either because it is soluble in both phases or because, being soluble in the medium only, it causes the globules to shrink, thus widening the passages for its entry. Doubtless water enters in the first way and this is probably true also of substances like urea, glycerine and the monatomic alcohols which appear to enter most cells very readily and regardless of the condition of the cell or the presence of other substances. Sodium chloride also enters readily when antagonistic salts are absent but it probably enters in the second way, that is by causing shrinkage of the globules. This is indicated by the fact that it also increases permeability for other substances as was shown, for instance, by Lillie for the pigment of *Arenicola* larvae.[10]

If a substance enters the cell only at times, as the amino acids and most salts appear to do, that is because it does not cause the globules to shrink and is therefore able to enter only when the condition of the cell or the effect of some other agent has caused sufficient shrinkage to provide a path adequate for entry. If a substance impedes the entry of another, as calcium chloride does for sodium chloride or for most dyes, that is because it has caused the globules to swell and thus to close more completely the paths between them. The explanation of antagonism is obvious.

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[10] Amer. Jour. Physiol. **24**: 23 (1909); **28**: 211 (1911).

The hypothesis outlined seems preferable to the "sieve" theory of Traube[11] and Ruhland[12] and to the "lipoid" theories of Overton[13] and Nathansohn[14] for the reason that it explains the frequent and normal changes of permeability for which those theories fail to account. Comparison with the recent hypotheses of Spaeth and of Clowes must be a little more detailed. Spaeth ascribed alteration of permeability to a change in the viscosity of the surface layer of the cell following a change in the "degree of dispersion" of the protoplasmic colloids. There is an uncertainty as to what is meant by "degree of dispersion." As commonly used this term refers to a change in the size of the dispersed particles of a colloid either by division of each of these particles into smaller ones (greater dispersion) or by aggregation of several particles into single larger ones (less dispersion). However, the context implies that Spaeth refers to swelling or shrinkage of the particles rather than to disintegration or aggregation of them. If this is so the Spaeth hypothesis differs from the present one only in that the mechanism by which swelling or shrinkage of the globules is brought about, namely, water exchange between the phases, is not suggested. Also, a regulation of permeability by restriction of the paths of entry between the globules would be much more effective and precise than any regulation which might be produced by the mere change of viscosity which Spaeth assumes. Such a change of viscosity would occur together with the change in size of the globules but would have much less effect on permeability.

The chief objection to the hypothesis of Clowes is that the phase inversion which it postulates would produce a change in the permeability relations of the cell much more sudden and complete than is actually observed. When phase inversion occurred the cell would cease all at once to be permeable to the set of substances soluble in one phase and become immediately permeable to another set of substances, namely, those soluble in the other phase. Such sudden changes of permeability do not appear to have been observed, nor has it been shown that increase of permeability to one set of substances is accompanied by decreased permeability to another set. These objections might be avoided in part by assuming a membrane in a state of mobile equilibrium so that parts of it are always in one phase relation and parts always in the inverted relation, or by assuming a state of frequent alternation of the membrane from one phase relation to the other. Such conditions are probably possible of occurrence theoretically as dynamic equilibria, but the balance would be extremely delicate and any slight disturbance would destroy it completely, creating the condition of entire and sudden reversal of permeability relations which does not appear to be the rule.

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[11] Arch. Anat. und Physiol. **1867**: 87–165.

[12] Jahrb. wiss. Bot. **46**: 1–54 (1909); Biochem. Zeits. **64**: 59–77 (1915).

[13] Vierteljahrschr. naturf. Ges. Zurich **44**: 88–135 (1899); Jahrb. wiss. Bot. **34**: 669–791 (1899).

[14] Jahrb. wiss. Bot. **39**: 607–644 (1904); **40**, 403–442 (1904).

In his second paper[15] Clowes presents experimental evidence for a parallelism between the effects of sodium hydroxide and calcium chloride in producing phase inversion in emulsions of olive oil and water and the effects of these same reagents on the permeability of protoplasm. But this parallelism does not establish that the two mechanisms are the same. Olive oil and water do not mix. Their emulsions do not have the property of ready exchange of water between the phases, which property characterizes the emulsoids of the gelatine type and probably the colloids of protoplasm. Nothing similar to olive oil occurs in the normal cytoplasm. The lipoid constituents of the cell are not oils and have been shown by Loewe[16] to be capable of forming with water, emulsoid colloids which appear to have this property of water interchange. But, even if these differences between the two cases are ignored, Clowes' evidence is not inconsistent with the hypothesis here suggested. It is quite possible that the swelling of the globules which is here postulated and the phase inversion which Clowes postulates could be produced by the same agent, for instance, calcium chloride, according to the concentration in which it is used. Thus the ultimate effect of adding an agent which caused swelling of the globules might be to produce phase inversion or, conversely, the initial effect of an inverting agent might be to make the globules swell. Although change in water distribution appears to be a simpler and more effective mechanism for the ordinary regulation of permeability, it does not follow that phase inversion is impossible as an extreme case of the same process. Both effects might result in turn from, for instance, a progressive change of the surface tension at the interface between the phases. The behavior of cells to ether, chloroform and other anesthetics is of interest. Small concentrations of these substances decrease permeability; large concentrations increase it.[17] The decrease is reversible; the increase is not. May not water interchange and phase inversion be in turn involved in these effects?

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[15] Jour. Phys. Chem., *loc. cit.*

[16] Biochem. Zeits. **42**: 150–218 (1912).

It must be borne in mind also that the result of long continued transfer of water between the phases is finally the same as though the phases had been inverted. A system consisting of a dilute external phase and a concentrated internal phase may become a system having a concentrated external phase and a dilute internal phase, not because of phase inversion by which the external phase has become the internal, but because of interchange of water by which the concentrated phase has become the dilute. The end result is the same; the path by which it was reached is different.

As to the chemical nature of the two phases which might exist in protoplasm and function in the way assumed, it is possible to say little. It is interesting, however, that the work of Loewe already mentioned indicates that some lipoid substances can form colloids of this type. The assumption of a lipoid-water colloid would explain the remarkable series of facts adduced by Overton in support of his lipoid theory as well as the facts which have been urged as inconsistent with this theory. In a sense this would be a revival of the "mosaic" theory of Nathansohn but on a different physical basis. In this connection it is of interest that Calugareanu[18] has observed a swelling of the globules of lecithin suspensions when ether or chloroform is added, the anesthetic being taken up by the suspension and presumably by the lecithin globules. Lillie[19] has suggested that anesthesia may be caused by a swelling of the lipoid particles due to the absorption of the anesthetic by them. In the case of the organic anesthetics such as ether and chloroform this explanation might be adequate though it is doubtful if the amount of anesthetic necessary to produce physiological effect is sufficient to cause any large degree of swelling of the particles by simple addition of volumes. The explanation is inadequate to account for the anesthetic effect of magnesium salts[20] and it seems more probable that if swelling of the particles (or globules) occurs in anesthesia it is secondary and due to an absorption of water caused by the anesthetic rather than to the added volume of the anesthetic itself.

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[17] Lillie, Amer. Jour. Physiol. **29**: 372-397 (1912); **30**: 1-17 (1912); Osterhout, Science **37**: 111-112 (1913).

[18] Biochem. Zeits. **29**: 96-101 (1910).

It is interesting that the hypothesis presented in this paper receives support from a series of facts which are not closely related to permeability. It has long been known that the "consistence" or viscosity of protoplasm is variable. Some protoplasm is practically liquid; some has the consistence of a stiff jelly. Recently two independent lines of investigation have shown that changes from liquid to semi-solid condition and vice versa may occur in living protoplasm spontaneously or under chemical or mechanical stimuli, and that these changes may be reversible. These investigations are the ultramicroscopic studies of Gaidukov,[21] Price[22] and others and the experiments of Barber,[23] Kite[24] and Chambers[25] on micro-dissection of the cell. Such changes of consistence are easily explainable as due to changes in the distribution of water between the phases. Similar changes in the simple colloids have been traced to this cause and no other adequate explanation is apparent for the case of protoplasm. It was in connection with this matter of protoplasmic viscosity that the present hypothesis was originally developed and I hope to discuss this phase of the subject in another paper at some future time.

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[19] Amer. Jour. Physiol. **29**: 395 (1912).

[20] Meltzer and Auer, Amer. Jour. Physiol. **14**: 361–388 (1905); Zentbl. Physiol. **27**: 632–635 (1913).

[21] Ber. deut. bot. Ges. **24**: 107–112, 155–157, 192–194, 581–590 (1906); Dunkelfeldbeleuchtung und Ultramikroskopie in der Biologie und der Medizin, 1910.

[22] Science Progress **8**: 343–354 (1913); Annals of Botany **28**: 601–532 (1914).

[23] Jour. infect. diseases **8**: 348–360; **9**: 117–129 (1911).

[24] Biol. Bull. **25**: 1–7 (1913); Amer. Jour. Physiol. **32**: 146–164 (1913); Kite and Chambers, Science **36**: 639–641 (1912).

[25] Science **40**: 824–827 (1914).

NOTE. The contents of this paper have been presented to the members of the journal clubs and seminars of a few universities and discussed with many individual workers. It was the intention of the author to revise it in several important particulars, but as he was ordered abroad on military service before this could be done, his consent was secured to publication in its present form.

Among other matters, the author would doubtless have taken into consideration the complex systems which may result when supposedly non-diffusible substances, such as the colloidal carbohydrates and the proteins, are brought together in one mass or system. Such arrangements are to be considered as including minute strands or filaments or lenticular, etc., masses of proteins, carbohydrates, etc., each in its own characteristic foam, honeycomb or sponge condition, the entire complex mutually interacting as to water relations. The interpolation of such posibilities into the hypothesis presented by Dr. Free would result in the multiplication of the reactions with regard to permeability in a very important manner.

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# ON THE DEVELOPMENT OF TWO PLANT ASSOCIATIONS OF NORTHERN MICHIGAN[1]

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It has been pointed out in an earlier paper[2] that the first stages in the development of a plant association are the immigration of species from the surrounding plant population and the selection from among them of those particular species which are adjusted to the local environment at that time. In the same paper it was also shown that the control of the physical environment by certain species of the selected immigrants is always an important feature of the environment and that ultimately the number of individuals of each species in the association is an index to the completeness and exactness of their adjustment to local conditions. Those species which exert the greatest measure of environmental control, thereby favoring their own multiplication and restricting that of other plants, are known as the dominant species of the association.

The development of an association on denuded ground therefore presents the following four stages: (1) immigration of numerous species, (2) selection[3] of those species adjusted to the physical environment, (3) the development of dominancy among certain species, and (4) the restriction in number or even complete extinction of the remaining secondary plants. These stages occur in the order stated, but the inception of one does not await the completion of the preceding. In fact, immigration and selection continue through the whole existence of the association. Any further changes in the association, aside from seasonal variations due to minor fluctuations in climate or other environmental factors, are slow in operation and generally illustrate succession rather than development.

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[1] Publication no. 170 from the Botanical Laboratory of the University of Michigan.

[2] Bull. Torr. Bot. Club 44: 463-481. 1917.

[3] It is easily understood that selection takes place by the elimination of unadjusted species, rather than by any sort of environmental choice.

Under favorable circumstances the development of dominancy proceeds rapidly and the span of a few years is sufficient for the association to reach maturity. When this stage is reached, the association remains essentially the same for an indefinite time, until it is finally succeeded by another.

One particularly favorable location for the rapid development of associations is on cleared land, where the soil is already in good condition for plant growth. Good illustrations of this type are abundant in northern Michigan, where logging operations are still in progress in the beech-maple forests.

The trees are felled in winter. The logs are piled where they can be reached easily by teams, and the brush and tops are thrown into small heaps which are so numerous that they cover at least a fourth of the ground surface. Numerous logging roads are built, which branch and intersect so that every pile of logs is reached.

Immigration of the species normally found in the beech-maple forest is of course easy. The seeds have been scattered during the previous autumn and, of some species, doubtless during the winter and following spring, while most of the perennials live uninjured under ground through the logging season. The following spring growth of the forest plants begins under greatly changed conditions. The light has increased from deep shade to full sunlight, the surface layers of the soil dry much more quickly, and the evaporation ratio is greatly increased. As a result, seeds do not germinate and most perennials die before the end of spring. Here and there scattered plants remain, small in size, seldom producing flowers, and with their leaves sunburned and misshapen. Under the partial shade of the edge of the brush-heaps more of them persist, but even there the number is much smaller than on an area of similar size in the original forest.

While environment is restricting the growth of many secondary species of the forest association, it is favoring certain others. In the original forest it is easily seen that *Acer pennsylvanicum*,[4] *Sambucus racemosa*, and *Rubus idaeus*, var. *aculeatissimus* are especially sensitive to shade and are always most abundant in the lightest spots. These three become the typical species of the clearing vegetation, associated with small numbers of various other species. Before the end of the summer numerous seedlings have developed, and their number is greatly increased the following year. Their growth is rapid, and by the third summer they have occupied the ground almost completely and have formed an almost impassible jungle a meter or more in height. This tangle of shrubbery serves as a nursery for seedling beeches and maples; particularly the latter, the seeds of which are produced more freely and are easily distributed by the wind. Several years must elapse before the young beeches and maples overtop the elders and raspberries, which then succumb to insufficient sunlight. The resulting maple thicket is now composed of saplings of approximately uniform age and height, and beneath it the usual secondary species are already appearing.

The time necessary to reestablish the maples as dominant species appears to be never less than five years under the best conditions, and it may be prolonged almost indefinitely by fires.

Tables 1, 2, 3, and 4 give the frequency indices[5] for the various species composing the original association and for three stages in its reestablishment after clearing, estimated in each case from counts of 100 two-meter quadrats. These were made on three different areas, not more than 500 meters apart, and in two different years.

While the logging operations are in progress, a large number of anthropochorous species are introduced. They are brought in

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[4] All names in this article follow the nomenclature of Gray's New Manual of Botany, seventh edition.

[5] The frequency index is the ratio, expressed in percentage, between the number of quadrats in which a species actually occurs and the total number of quadrats counted. If 100 quadrats are counted, the index is expressed directly by the number of quadrats for any species. Thus, in Table 1, seedlings of Acer saccharum occurred in 92 of the 100 quadrats counted. In determining the frequency index, no attention is paid to the number of individual plants. Nevertheless, there is a direct relation between frequency and number of individuals, so that a high index is invariably associated with large numbers.

TABLE 1

*Virgin beech-maple forest, 1915. Frequency indices for secondary species only*

| | | | |
|---|---|---|---|
| *Acer saccharum* seedlings | 92 | *Clintonia borealis* | 7 |
| *Fagus grandifolia* seedlings | 74 | *Streptopus longipes* | 5 |
| *Maianthemum canadense* | 46 | *Trientalis americana* | 4 |
| *Smilacina racemosa* | 37 | *Galium triflorum* | 3 |
| *Acer pennsylvanicum* | 28 | *Medeola virginiana* | 3 |
| *Polygonatum biflorum* | 22 | *Sambucus racemosa* | 3 |
| *Streptopus roseus* | 18 | *Actaea alba* | 1 |
| *Aspidium spinulosum* | 12 | *Rubus idaeus*, var. *aculeatissimus* | 1 |
| *Aralia nudicaulis* | 8 | | |

Present in the immediate vicinity, but not in the quadrats counted: *Aralia racemosa, Circaea uteliana, Dirca palustris, Epifagus virginiana, Epilobium angustifolium, Hieracium venosum, Mitchella repens, Monotropa uniflora, Ostrya virginiana* seedlings, *Pyrola elliptica, Trillium grandiflorum, Tsuga canadensis* seedlings, *Ulmus fulva* seedlings.

TABLE 2

*Clearing vegetation, first year, 1915*

| | | | |
|---|---|---|---|
| *Acer pennsylvanicum* | 18 | *Fagus grandifolia* seedlings | 3 |
| *Maianthemum canadense* | 6 | *Trillium grandiflorum* | 2 |
| *Sambucus racemosa* | 5 | *Chenopodium capitatum* | 1 |
| *Rubus idaeus*, var. *aculeatissimus* | 5 | *Lactuca canadenis* | 1 |
| *Acer saccharum* seedlings | 4 | *Smilacina racemosa* | 1 |

Present in the vicinity, but not in the quadrats counted: *Anaphalis margaritacea, Epilobium, angustifolium, Erechtites hieracifolia, Mitchella repens, Polygonatum biflorum, Trientalis americana.*

TABLE 3

*Clearing vegetation, third year, 1917*

| | | | |
|---|---|---|---|
| *Sambucus racemosa* | 86 | *Anaphalis margaritacea* | 8 |
| *Rubus idaeus*, var. *aculeatissimus* | 64 | *Fagus grandifolia* seedlings | 7 |
| *Acer pennsylvanicum* | 57 | *Pteris aquilina* | 7 |
| *Acer saccharum* seedlings | 56 | *Gnaphalium decurrens* | 5 |
| *Epilobium angustifolium* | 35 | | |

Present in the vicinity, but not in the quadrats counted: *Betula alba*, var. *papyrifera, Epilobium adenocaulon, Erigeron canadensis, Maianthemum canadense, Populus grandidentata, Populus tremuloides, Smilacina racemosa.*

TABLE 4

*Clearing vegetation, at least eight years old, 1917*

| | | | |
|---|---|---|---|
| *Acer saccharum* | 100 | *Trillium grandiflorum* | 3 |
| *Acer pennsylvanicum* | 11 | *Clintonia borealis* | 2 |
| *Maianthemun canadense* | 6 | *Mitchella repens* | 1 |
| *Fagus grandifolia* | 5 | | |

Numerous other species occur widely scattered through the area.

in hay, in packing material, and doubtless in other ways also, and are distributed through the clearing along all of the logging roads. They are all common field and roadside weeds of the neighboring farming region or ruderal plants of the city of Cheboygan, to which the lumber is hauled. Away from the settlements their distribution is restricted completely to areas more or less modified by human activity, as has been described in another place.[6]

These species demand full sunlight for their successful growth, and consequently develop rapidly during the first summer. At that time the premises of the logging camp, every logging road, every site of a log pile and every feeding ground are marked by an assemblage of foreign species, occurring as scattered individuals but greatly outnumbering the few relics of the forest. Owing to the great seed production so characteristic of weeds, their numbers are vastly increased during the second summer. By the third summer one species, *Poa pratensis*, and frequently another, *Phleum pratense*, have become so abundant that they form extensive patches of sod, which occupy the camp grounds and extend in narrow lines along every logging road. In short, every part of the original forest which has been accessible to horses and wagons is converted in three years into a blue grass meadow, which forms a striking contrast to the tangle of shrubbery hemming it in on all sides.

Elimination of species begins with the establishment of a sod, and by the third summer several species of the first year have disappeared. Of the remainder, the majority are restricted to the edge of rubbish heaps or sawdust piles, to the base of the walls of buildings, or to small and dense colonies within the meadow. In such places they may resist the further encroachment of the meadow for many years, as evidenced below. A minority, on the other hand, seem well adapted to the sod and are found widely distributed over it. These species are *Trifolium pratense*, *Trifolium hybridum*, *Trifolium repens*, *Agrostis alba*, and *Rumex acetosella*.

It is noteworthy that these foreign species are virtually independent of the local physical environment. The logging roads frequently descend gentle slopes and cross a narrow marsh in the valley, without any change in the composition of the flora except the addition of *Ranunculus acris.* There is, however, some change in the relative abundance of the various species, and in the size and luxuriance of the individuals. Similar areas of the blue grass association occur throughout the uncultivated region, on clay and on sand, on upland and on lowland, on forest clearings and on abandoned farms, and all exhibit the same vegetational structure. The association is therefore a product of human activity and not of physical environment alone.

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[6] Bull. Torr. Bot. Club 41: 511–521. 1914.

Tables 5 and 6 illustrate the structure of the blue grass association at two stages of its development in clearings.

TABLE 5

*Blue grass association, first year, 1915*

| | | | |
|---|---|---|---|
| *Poa pratensis* | 16 | *Epilobium angustifolium* | 2 |
| *Phleum pratense* | 11 | *Erigeron canadensis* | 2 |
| *Trifolium hybridum* | 9 | *Lepidium virginicum* | 2 |
| *Polygonum convolvulus* | 5 | *Anaphalis margaritacea* | 1 |
| *Trifolium pratense* | 5 | *Cirsium arvense* | 1 |
| *Capsella bursa-pastoris* | 4 | *Gnaphalium decurrens* | 1 |
| *Trifolium repens* | 4 | *Hieracium aurantiacum* | 1 |
| *Cerastium vulgatum* | 3 | *Lappula echinata* | 1 |
| *Chenopodium capitatum* | 3 | *Lychnis alba* | 1 |
| *Cynoglossum officinale* | 3 | *Sisymbrium officinale* | 1 |
| *Rumex acetosella* | 3 | | |

Twenty other species also occurred in the association, but not in the quadrats counted.

TABLE 6

*Blue grass association, third year, 1917*

| | | | |
|---|---|---|---|
| *Poa pratensis* | 96 | *Pteris aquilina* | 5 |
| *Phleum pratense* | 21 | *Capsella bursa-pastoris* | 4 |
| *Trifolium hybridum* | 13 | *Cirsium arvense* | 4 |
| *Trifolium pratense* | 10 | *Arenaria serpyllifolia* | 3 |
| *Rumex acetosella* | 9 | *Lychnis alba* | 3 |
| *Trifolium repens* | 8 | *Rumex elongatus* | 2 |
| *Agrostis alba* | 8 | *Chrysanthemum leucanthemum* | 1 |
| *Poa compressa* | 6 | *Cynoglossum officinale* | 1 |

Twenty other species also occurred in the association, but not in the quadrats counted.

A similar development of the same association takes place in abandoned fields. The first season after cultivation the field is occupied by numerous species of introduced weeds. Among them *Poa pratensis*, sometimes associated with *Phleum pratense*, soon becomes dominant, the species and individuals of other weeds are reduced in number, and in a short time the blue grass meadow is developed. Table 7 exhibits in parallel columns the structure of the same field in 1914 and 1917. This field was plowed in 1913 and has since then been abandoned.

It is not known how long the blue grass association may persist. It is still well developed in numerous places in the aspen region, which was formerly occupied by pine forest and was lumbered over thirty years ago. The introduction of the blue grass was doubtless contemporaneous with the logging, and the association now marks the site of feeding grounds and logging roads. Numerous other species still occur with the blue grass along roads now in use, but isolated areas frequently contain no other foreign species, or *Chrysanthemum leucanthemum* alone. Other species, which may have been associated with the blue grass formerly, have succumbed under the competition with the blue grass sod.

The association still presents a considerable number of secondary species around an old mill, abandoned at least seven years ago. Here they are in general restricted to the sawdust heaps, to the base of walls, and in some cases to the inside of abandoned stables. Thirty-six species were listed about the premises in 1917, and two additional species occurred within the stables only.

The ultimate fate of the association depends entirely upon its relation to continued human activity. Usually the logging camps and roads are abandoned when the lumbering is completed. A young forest develops rapidly at the margin of the blue grass association and gradually encroaches upon it. At the same time scattered individuals of forest species succeed in establishing themselves within the main body of the association, and by their shade contribute to the destruction of the blue grass and the eventual reappearance of the forest. Among these pioneers *Rubus idaeus*, var. *aculeatissimus* and *Acer saccharum* are conspicuous in the succession by the beech-maple forest, and *Rhus glabra* and *Prunus pennsylvanica* in the succession by aspens, leading ultimately to a pine forest. Indications of the former are shown in table 8. If the development of the surrounding forest is restricted by further clearing or by fire, the blue grass association probably continues indefinitely.

TABLE 7

*Development of blue grass association. Frequency indices based on 15 two-meter quadrats*

| | 1914 | 1917 |
|---|---|---|
| *Poa pratensis* | 93 | 100 |
| *Pteris aquilina* | 100 | 93 |
| *Verbascum thapsus* | 80 | 27 |
| *Chenopodium album* | 100 | 0 |
| *Sisymbrium altissimum* | 87 | 0* |
| *Erigeron canadensis* | 67 | 0 |
| *Polygonum convolvulus* | 67 | 0 |
| *Taraxacum officinale* | 53 | 7 |
| *Setaria glauca* | 47 | 0 |
| *Rubus idaeus*, var. *aculeatissimus* | 13 | 33 |
| *Aralia hispida* | 0 | 33 |
| *Secale cereale* | 33 | 0 |
| *Lepidium virginicum* | 27 | 0* |
| *Rhus glabra* | 13 | 13 |
| *Prunus pennsylvanica* | 13 | 7 |
| *Triticum sativum* | 20 | 0 |
| *Epilobium angustifolium* | 7 | 7 |
| *Agrostis alba* | 7 | 0 |
| *Amaranthus retroflexus* | 7 | 0 |
| *Apocynum androsaemifolium* | 7 | 0 |
| *Capsella bursa-pastoris* | 7 | 0 |
| *Fagopyrum esculentum* | 7 | 0 |
| *Gnaphalium decurrens* | 0 | 7 |
| *Solidago canadensis* | 0 | 7 |

*Present in the association but not in the quadrats counted.

TABLE 8

*Development of blue grass association. Frequency indices based on 15 two-meter quadrats*

| | 1914 | 1917 |
|---|---|---|
| *Poa pratensis* | 100 | 100 |
| *Erigeron canadensis* | 93 | 0* |
| *Rubus idaeus*, var. *aculeatissimus* | 80 | 87 |
| *Verbascum thapsus* | 60 | 0* |
| *Chenopodium album* | 53 | 0 |
| *Polygonum convolvulus* | 53 | 0 |
| *Lepidium virginicum* | 40 | 0 |
| *Sisymbrium altissimum* | 40 | 0 |
| *Gnaphalium decurrens* | 20 | 0 |
| *Agrostis alba* | 13 | 0 |
| *Epilobium angustifolium* | 13 | 7 |
| *Amaranthus blitoides* | 7 | 0 |
| *Aralia hispida* | 7 | 7 |
| *Panicum capillare* | 7 | 0 |
| *Prunus pennsylvanica* | 7 | 7 |
| *Sambucus racemosa* | 7 | 0* |

*Present in the association but not in the quadrats counted.

Additional species present in the association in 1917, but not in the quadrats counted, and not present in 1914: *Acer saccharum* seedlings, *Phleum pratense*, *Pteris aquilina*, *Rhus glabra*, *Rubus allegheniensis*, *Solidago canadensis*, *Taraxacum officinale*.

# BOOKS AND CURRENT LITERATURE

**Culture of Mistletoes.** The first results of an extended series of experiments on the culture of mistletoes have been published by Weir,[1] whose interest in these plants is that of the forester investigating one of the serious enemies of forest trees. The work was begun in 1911 and has been carried out in the northwestern states, chiefly at Missoula, Montana. Some of the cultures were made in the open and some of them in the greenhouse. The inoculations were effected by soaking the seeds of the parasites and allowing them to dry on the twigs and young branches of the hosts. No inoculations were attempted on branches more than six years old. The success of the method was demonstrated by the ease with which it was possible to establish each of the parasites on the host tree which it most commonly attacks, or for which it exhibits an "affinity," to use the wording of the author. Species of *Razoumofskya* were also established on hosts which they seldom inhabit in nature, as well as on related trees from regions in which this genus of mistletoes does not occur. Important information has thus been obtained that will aid in preventing the dissemination of western mistletoes by introducing nursery stock into eastern forests or plantations in which new hosts might be attacked. For example *Razoumofskya laricis* mainly affects *Larix occidentalis* but can be made to grow on *Larix lyallii, L. europaea, L. leptolepis, Abies grandis, Pinus ponderosa* and *P. contorta*. Negative results were secured from inoculations made on twelve other species of conifers and on *Alnus, Betula* and *Salix*. *Razoumofskya americana* is commonly found on *Pinus contorta* and *P. banksiana*, but was made to grow on six other pines, with negative results on fifteen species of *Larix, Abies, Picea*, etc. It is pointed out that when the same strain of mistletoe is grown on several hosts there are morphological differences between the resulting plants, which have been used—in one or two cases—as a basis for the description of distinct species. Other differences which have been used in classification—notably those of color—appear to be due to climatic conditions.—Forrest Shreve.

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[1] Weir, James R. Experimental investigations on the genus *Razoumofskya*. Bot. Gaz. **67**: 1–31. 1918.

Vegetation of South Africa.—A very brief account of the vegetation of South Africa below Lat. 22° S. has been published by Evans.[1] The leading components of the several types of vegetation are listed, but little attempt is made to describe the vegetational characteristics of these areas. The woodland vegetation is subdivided into forest and scrub, areas which are confined to the immediate vicinity of the Cape; into bush-veld, found mainly in the Transvaal; and palm forest, skirting the eastern coast down to Lat. 32°. The grassland is subdivided into high veld, occupying southern Transvaal and Orange Free State; thorn veld, lying in Natal and eastern Cape of Good Hope; and the Kalahari grassland, lying in the interior. The desert areas are those of the Namib, lying on the Atlantic coast; Namaqualand, lying in the western interior; the Karroid plateau, in northern Cape of Good Hope; and the Karroo, adjacent to the scrub and forest of the Cape. An excellent series of 48 illustrations conveys a vivid impression of these types of vegetation, and a colored map shows their general distribution. In spite of the much more detailed work of Marloth it is of interest to have this addition to our knowledge of the vegetation of one of the most diversified of all the regions which are in danger of profound alteration through human agency. One of the greatest limitations to the economic development of the Union of South Africa is most patently shown on the vegetation map in the extremely small size of the forested area.—Forrest Shreve.

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[1] Evans, I. B. Pole. The Plant Geography of South Africa. Official Year Book, Union of South Africa. Pretoria, 1918.

## NOTES AND COMMENT

Dr. T. H. Kearney, of the Bureau of Plant Industry, has written an interesting account of Plant Life on Saline Soils, which was delivered as the address of the retiring President of the Botanical Society of Washington in February, 1918 (Jour. Wash. Acad. Sci., March 1918). This is a subject in which Dr. Kearney has had wide experience and his conclusions will therefore command much respect. He seems, however, to have missed many important contributions of the last few years and says: "Comparatively few determinations have been made of the osmotic pressure in the roots of halophytes." No reference whatever is made to the work of Harris, Lawrence and others, which surpasses the work of previous contributors in adequacy, exactness and general importance. Their papers are easily accessible. Some of them have been published in American journals as follows:

HARRIS, J. ARTHUR, JOHN V. LAWRENCE AND ROSS AIKEN GORTNER. On the osmotic pressure of the juices of desert plants. Science, n. s., **40,** 656–658 (Apr. 1915).

HARRIS, J. ARTHUR, AND J. V. LAWRENCE, with the cooperation of R. A. GORTNER. The cryoscopic constants of expressed vegetable saps as related to local environmental conditions in the Arizona deserts. Physiol. Researches, **2,** 1–49 (1916).

HARRIS, J. ARTHUR. Physical chemistry in the service of phytogeography. Science, n. s., **46,** 25–30 (July 1917).

HARRIS, J. ARTHUR, AND JOHN V. LAWRENCE. The osmotic concentration of the sap of the leaves of mangrove trees. Biol. Bull., **32,** 202–211 (March 1917).

HARRIS, J. ARTHUR, AND JOHN V. LAWRENCE. The osmotic concentration of the tissue fluids of Jamaican montane rain forest vegetation. Amer. Jour. Bot., **4,** 268–298 (May 1917).

—D. T. MACDOUGAL.

The Geographical Review has recently published a paper by Dr. Carl Skottsberg on the botanical features of the Juan Fernandez Islands (May 1918). The two islands which form this group lie 360 and 450 miles from the Chilean coast. Their topography is extremely rugged, and the smaller island reaches an altitude of 5300 feet although it is only eight miles long. The small bodies of forest occupying the valleys and higher slopes are rich in members of widely distributed Pacific genera and in peculiar endemic species. Among the latter are the palm *Juania australis*, the woody composites *Dendroseris* and *Robinsonia*, which have a miniature arborescent habit, *Gunnera masafuerae*, which has leaves ten feet in diameter, and the archaic fern *Thyrsopteris*. At least one plant peculiar to the islands—a sandalwood—has been exterminated. On the highest plateaus are found many species common to southernmost South America. The excellent illustrations accompanying the paper give a vivid conception of the natural features of these little-visited islands.

Through the initiative of the Waycross Progress Club, of Waycross, Georgia, a movement has been started for the preservation of Okefinokee Swamp, which is in danger of rapid spoliation by draining and lumbering operations. Dr. J. F. Wilson, Secretary of the Progress Club, is endeavoring to interest as many persons as possible in the formation of an Okefinokee Society for the active promotion of plans to have at least a portion of the swamp set aside as a state or national preserve. The great biological interest of the swamp should elicit the coöperation of botanists and zoölogists in this plan. It is to be hoped that both individuals and scientific societies will give prompt aid to such a worthy movement.

Mr. J. G. Millais has published an elaborate quarto volume on the horticultural aspects of the genus *Rhododendron*, with numerous colored plates (Longmans, Green and Company). The history of the cultivation of these plants is given, together with descriptions of all species and hybrids, and a discussion of the soil and climatic conditions which they require.

Among the papers which will appear in forthcoming issues of The Plant World are the following: Root Habit and Plant Distribution in the Far North, by Howard E. Pulling; The History of the Linden and Ash, by Edward W. Berry; Porous Clay Cones for the Auto-Irrigation of Potted Plants, by B. E. Livingston; The Genus *Morinda* in the Hawaiian Flora, by Vaughan MacCaughey; Temperatures of Small Fruits when Picked, by Neil E. Stevens and R. B. Wilcox; and A Promising Chemical Photometer for Plant Physiological Research, by Charles S. Ridgway.

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# THE HISTORY OF THE LINDEN AND ASH

EDWARD W. BERRY

*The Johns Hopkins University*

## THE ASH

Few except professional botanists realize that our familiar ash of southeastern North America is a member of the Olive family, or Oleaceae as it is known scientifically. This family of plants, named originally from the Mediterranean olive, now extensively cultivated in California, contains a number of other well known plants, both native and introduced, some of which are greatly prized for ornamental planting. The devil-wood (*Osmanthus*) of our Gulf states, sometimes called the American olive, belongs in this family, as do the lilac, forsythia, privet, syringa and jasmine.

The two principal areas of distribution of the existing ashes are southeastern North America and southeastern Asia although they are not wanting in Europe or along the west coast of North America. There are about the same number of species of ash in China as there are in North America but those of the latter region are usually larger trees and yield a more valuable timber. In addition to the ash two other genera of the Olive family, namely, *Chionanthus* and *Osmanthus*, are common to China and our southeastern states—in the former country *Osmanthus* flowers are used for the scenting of tea.

Obviously *Fraxinus*, *Chionanthus* and *Osmanthus* did not originate simultaneously or at different times in Asia and North America, and there must have been a time when these outlying centers of distribution were connected. On a subsequent page we shall see that this is clearly shown in the case of the ash (*Fraxinus*), and the presence of a fossil *Osmanthus* in the early Eocene of Tennessee indicates that this genus also is an ancient

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one that formerly migrated between Asia and North America at a time when climates were more suitable for such a migration than they are at the present time, a time when a land bridge united the two continents across the present Behring Sea region.

The ashes have handsome, usually compound leaves consisting of a greater or less number of separate leaflets arranged in a pinnate manner on a central stipe. Their leaves are thus similar to those of the walnuts and hickories, but may readily be distinguished by their opposite arrangement on the branches—the walnut and hickory leaves being arranged in an alternate manner.

The generic name *Fraxinus* for the ash genus is derived from the classical name of the European ash, and the common name doubtless refers to the ashy color of its branches. Ash flowers are not conspicuous but the winged fruits, technically known as samaras, are borne in panicles and are familiar to all that tramp the fall woods, each fruit resembling a tiny canoe paddle.

The wood is tough, straight grained and that of some of the species is a most valuable timber. In Britain ash lumber ranks next to that of the oak in importance. In this country ash is one of the leading commercial hardwoods and the annual cut which amounts to about $10,000,000 in value probably exceeds the annual growth increase in the supply, so that soon we will be obliged to bestir ourselves and do intensive cultivation or see the important industries that use ash lumber pinched by scarcity and consequent higher prices or obliged to use inferior substitutes.

Ash timber has such special uses that it is too valuable to be used for ordinary construction purposes. These uses all depend on its straightness of grain, elasticity, strength, hardness, and the characteristic of wearing smooth with use. Among these special uses the making of handles, which the layman might think unimportant, utilizes about 22% of the total cut with a value of about $2,000,000 annually. Next in importance has been the use of ash for butter tub staves and other dairy supplies, which consumes over 20%, of the annual cut. Vehicle manufacturers take about 15%, while planing mills use large amounts and the manufacturers of boat oars consume about a quarter of a million dollars worth of ash lumber every year.

Next to spruce ash is the most important wood used in aeroplane construction. It enters into frames, outriggers, skids, rudders and propellers. As recently as 1914 this use amounted to less than one-one-hundredth of 1% of the annual cut, but at the present time this percentage must be very much greater. Ash, chiefly black ash, enters largely into bent frame parts as well as for slats and splints in basketry. The early settlers in New England learned from the Indians who were accomplished in this handiwork the art of making baskets that lasted a lifetime of ash splints and strips.

The production of Chinese or Insect white wax (Peh-la) is, next to agriculture or sericulture, the most important industry in certain parts of China (Szechuan). This wax is deposited by a scale insect on a species of ash (*Fraxinus chinensis*). The insects are bred on a privet (*Libustrum lucidum*) which does not grow in the immediate vicinity of the ash plantations so that the eggs must be carried rapidly by coolies a distance of over 150 miles to the ash plantations. This wax is highly valued by the natives and since it does not melt until temperatures around 180° are reached it makes valuable candles, but its value is such that it is usually used merely for outer coatings. It is also used for coating pills, polishing jade, soapstone and delicate furniture, or as a size to give a lustre to cloth. Its most extensive use is for glossing the high grade papers of native manufacture. A somewhat remotely comparable product is obtained from the Manna ash (*Fraxinus ornus*) of Mediterranean Europe. This is the manna of commerce and is not a true wax but a secretion whose chief constituent is mannite or manna sugar. It is obtained in commercial quantities entirely from Sicily and unlike the Chinese wax it is not due to the activity of scale insects but is obtained by making incisions in the bark. It is thus not related to the manna of the Scriptures, which was due to the punctures of scale insects working on *Tamarix* trees.

There are upwards of fifty existing species of ash and they are widely distributed throughout the temperate regions of Eurasia and North America, extending into the Tropics in both the Eastern (Java) and the Western (Cuba) Hemispheres. Their generalized limits of distribution together with the known fossil occurrence of the ash ore are shown on the accompanying sketch-map. The American species number from 18 to 24 according to the varying conceptions of different students as to what constitutes a species. Three of these (*Fraxinus breggii*, *F. cuspidata* and *F. dipetala*) are shrubby forms of the southwest. The three important commercial species are the white ash (*Fraxinus americana*), the green ash (*Fraxinus lanceolata*) and the black ash (*Fraxinus nigra*). The lumber trade, however, may only recognize white or dark ash, or more often simply ash, and all or some of the other species that are cut go to swell these categories.

The white ashes, which include the species *F. americana*, *F. texensis* and *F. biltmoreana* are upland forms. The green ashes, which include a large number of less important species than the important *Fraxinus lanceolata* (namely *F. darlingtonii*, *F. michauxii*, *F. profunda*, *F. berlandieriana*, *F. pennsylvanica*, *F. oregona*, *F. velutina*, *F. toumeyi*, and *F. coriacea*), are broadly speaking bottom land dwellers. The water ashes, *Fraxinus caroliniana* and *F. pauciflora* are swamp trees: while the black ashes, *Fraxinus quadrangulata*, *F. anomala* and *F. nigra* are trees of what might be called unfavorable situations such as dry hills and cold swamps. The shrubby species are chaparral and upland forms of the arid southwest.

The geographical extent of the different existing species seems to be determined very largely by the lightness and durability of the seeds and their quickness of germination combined with the frequency of seed years, that is to say the factors are largely those of seed dispersal. In accordance with this dictum it has been found that the so-called green ashes are the most aggressive and widely distributed; the white ashes are but little less so; while the water ashes and the black ashes seem to be the least fitted for maintaining their present range.

Not all of the trees called by the name of ash are related to the true ashes—thus the poison-ash of our eastern states is a species of sumach (*Rhus*); the bitter ash of the West Indies is a species of *Simaruba;* the Cape Ash of South Africa is a species of *Ekebergia;* the prickly ash of our eastern states is a *Xanthoxylon;*

and the familiarly cultivated mountain ash of America and Europe are related species of the genus *Sorbus* and belong to the Rose family (Rosaceae), in fact none of these that I have enumerated belong to the same plant family as the true ash.

The earliest fossils that have been referred to the ash (*Fraxinus*) are leaves, whose identity is not conclusive, from what are called the Patoot beds of western Greenland. These deposits are of late Upper Cretaceous age and are underlain in that region by the older Atane beds which also contain an extensive flora with walnuts, figs, magnolias, persimmons, poplars and other species of ancestral trees, but no traces of ashes. The correctness of the identification of these Patoot species of ash is really of but slight importance for these deposits are immediately overlain by a series of lignitic shales and basalts of early Tertiary age and an abundant flora is found associated with the lignite in which the leaves of an ash are found. These leaves are almost certainly those of an ash since they also occur in the Eocene of southeastern North America associated with characteristic ash fruits. The history of *Fraxinus* thus is known to go back at least as far as the dawn of the Tertiary period, an epoch estimated to date from at least three million years ago, to a time which antedates the appearance of the ancestral polydactyl horses, or for that matter any of the lines leading to the higher mammalia.

About a dozen Eocene species of *Fraxinus* are known. They are found from Greenland to Louisiana and from Alaska to Oregon, Colorado and Wyoming. Their remains include leaves and characteristic fruits, specimens of both of which of this age are shown on the accompanying plate. All of these Eocene forms that have thus far been discovered are either North American or Arctic American—none having been found in the abundant Eocene floras of Eurasia. It therefore seems probable that the genus originated at some time during the late Cretaceous on either the North American mainland or in the region immediately to the north of it. Very little is known of the geologic history of plants in the vast region of Asia, but if the ash had originated on the latter continent it should have spread to Europe, where Eocene plant beds are so common, about as quickly as it did to North America. This fact and the large number of American Eocene species fortify the conclusion that the early ash was an American product.

However, the ash was well on its way toward Europe for during the succeeding Oligocene the leaves and fruits are found at a large number of localities on that continent, from the amber beds on the shores of the Baltic to the gypsum beds along the shores of the Gulf of Lyons. Ten different forms of Oligocene ash are known and these are all European, since Asia remains unknown and in North America the deposits of Oligocene age are largely marine marls or limestones along the continental borders or flood plain and channel deposits in the interior in which fossil plants seem to be rarely found. Two fruits of Oligocene ashes from Europe are shown on the accompanying plate.

Passing to Miocene times, which succeeded those of the Oligocene, we find *Fraxinus*, like most of the other tree genera, to have been widespread, diversified and common, and probably more abundant than at the present time—their geographical range was certainly more extensive then than now. Over thirty different ashes are known from Miocene deposits. They are found in North America in Oregon on the west coast and in Virginia on the east coast. A hint at their probable abundance at this time in the Rocky Mountain region is given to us by the lake deposits at Florissant, Colorado, where the fortunate preservation of the sediments of this tiny lake basin furnish an unparalleled picture of the insect and plant life of Miocene times in that region.

No less than seven species of ash have been discovered in these Florissant beds, thus indicating that the ash was much more abundant and diversified at that time than would otherwise have been suspected from a consideration of the rather infrequent Miocene plant beds of other parts of North America. *Fraxinus* is present in all of the more important Miocene plant bearing deposits throughout Europe, and it appears to have been especially abundant in late Miocene times along the shores of the Mediterranean and in the uplands of central France, southern

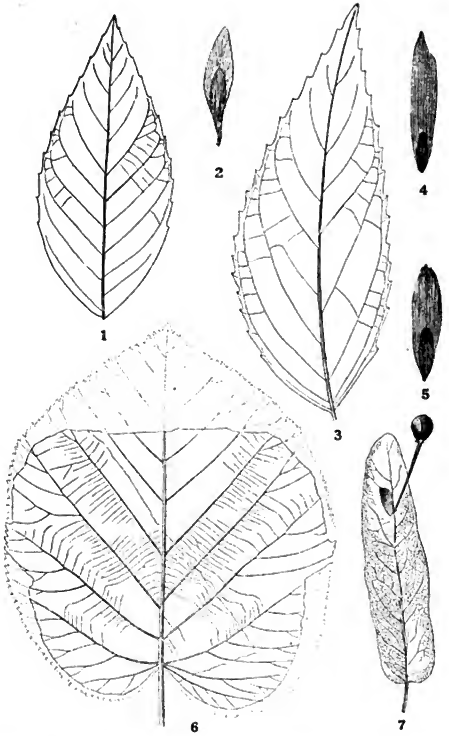

Fig. 1. 1, *Fraxinus richmondensis* Berry from the Miocene of Virginia; 2, *Fraxinus wilcoxiana* Berry from the lower Eocene of Tennessee; 3, *Fraxinus Johnstrupi* Heer from the upper Eocene of Greenland; 4, *Fraxinus juglandina* Saporta from the Oligocene of France; 5, *Fraxinus ulmifolia* Saporta from the Oligocene of France; 6, *Tilia Malmgreni* Heer from the upper Eocene of Spitzbergen; 7, *Tilia vindobonensis* Stur from the upper Miocene of Hungary.

Germany, and in the various crown-lands of the Austrian monarchy. An ash leaf from the Miocene of Virginia is shown on the accompanying plate.

Ashes seem to have declined in variety during the succeeding Pliocene times, and the few species that have been discovered all show a near approach in their characters to those of the existing species. Thus in Spain, France and Italy fossil leaves are found in the Pliocene deposits that are indistinguishable from those of the existing manna ash (*Fraxinus ornus*) of southern Europe. Similarly modern looking ash leaflets are found in the Pliocene Citronelle formation in our Gulf states.

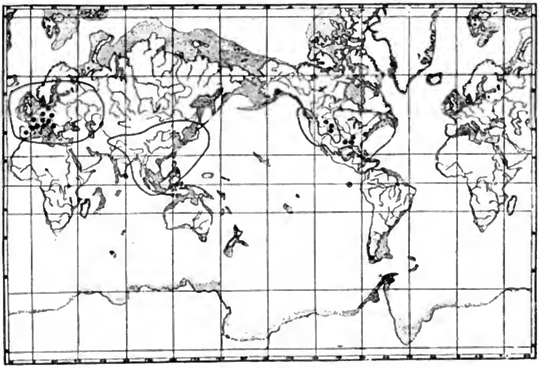

Fig. 2. Sketch map showing the existing and fossil distribution of *Fraxinus*.

During the succeeding Pleistocene times, marked by continental ice sheets, the ashes that have been found fossil are all still existing species, and include at least two European and two American forms. These all occur either far to the southward of the ice sheets, as for example *Fraxinus ornus* in Italy, or in Interglacial deposits, as for example *Fraxinus excelsior* in France and Germany. In this country our white ash, *Fraxinus americana,* is found in the early Pleistocene of western Kentucky and the late Pleistocene of Maryland; the existing blue ash (*Fraxinus quadrangulata*) of the Mississippi valley was present and pushed northward as far as the Don Valley in Canada during an Interglacial period when the climate for a time was somewhat warmer than it is at the present time in the same latitude.

## THE LINDEN

The family Tiliaceae to which the Linden belongs comprises about 35 genera and upwards of 400 existing species. These are chiefly tropical, and they are massed in two general regions—one around the Indian Ocean and the other in northern South America. The number of genera that have known fossil representatives is unfortunately limited to ancestral forms of the linden (*Tilia*), to the genus *Grewiopsis* which is ancestral to the existing oriental species of *Grewia,* to *Apeibopsis* which is ancestral to the South American genus *Apeiba,* and to the South American genus *Luhea.* All of these indicate that in former times the geographical distribution of the various members of this family was very different from what it is at the present time.

The genus *Tilia,* which gives its name to the family, although belonging to a family that is essentially tropical, is itself confined to the North Temperate Zone, occurring on all of the great northern land masses, but now absent in western North America, in central Asia, and in the Himalayan region. All of the existing species are trees, all have similar simple alternate leaves with free stipules, all have similar flower clusters borne on a large leaf-like bract, and the fruits are nut-like, although some of the members of the family have capsular fruits.

The wood is pale in color and soft, but straight grained and easily worked. In America it is commonly known as whitewood, although the terms basswood and linn are also frequently applied to it. Pulp mills consume large amounts of timber annually and the lumber enters very largely into interior finish and planing mill products, cheap furniture, turnery and similar uses.

There are about a score of existing species, about equally divided between North America, Europe and Asia. Apparently all of these have very fragrant flowers, rich in nectar, and thus the source of large amounts of honey—the light colored basswood honey of the trade. This utility, especially in the earlier days of the race, has made the linden a favorite tree and we find it mentioned by Theophrastus, Pliny, Virgil, Aristophanes and other early writers. Aside from the compact handsome form of the tree and the beauty of its foliage I suspect that the association with bee keeping and the distillation of the oil from the flowers for use in perfumery has something to do with the widespread custom of planting both the American and the European species as shade trees, even though most of humanity is no longer fortunate enough to keep bees.

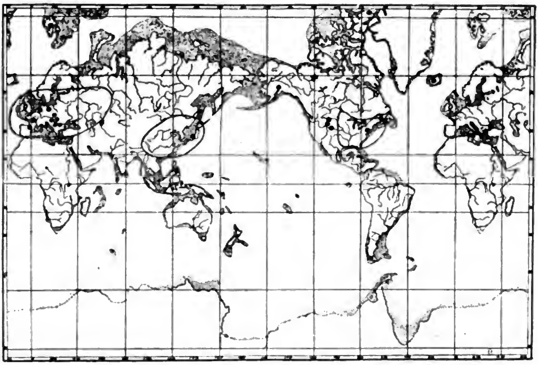

Fig. 3. Sketch map showing the existing and fossil distribution of *Tilia*.

The various species of linden in this country go by the names of linden or basswood, less frequently they are called bee trees or linns, although the last name is common in certain southern s ates. Very infrequently are these trees called limes in this country although the latter name is perhaps the one most commonly applied to them in Europe, where it is derived apparently as an altered form of the old English lind.

Some of the species grow to a great size, Ray mentioning a European tree that was 48 feet in circumference, although this seems an unusual size. The famous lime tree that gave the town of Neuenstadt in Württemberg the appellation of "Neuenstadt an der grossen Linden" was 9 feet in diameter. Many of our American streets are lined with linden trees, often the European form, and most of the larger eastern cities have a Linden Avenue. Perhaps the two most famous avenues of lindens, however are those at Trinity College, Cambridge, and "Unter den Linden" in Berlin. In the more remote regions where wood carving is not a lost art linden wood is very largely used for this handicraft, and in backward countries like much of Russia the bast or inner bark of the linden is used in the manufacture of cords, fish nets and similar articles. Bast mats made of this material are a regular article of commerce and are largely imported from Russia.

The generalized range of the existing species and the known fossil occurrences of the lindens are shown on the accompanying sketch map. The number of fossil species is inconsiderable comprising not more than thirty different forms, which is really a small number when one reflects on the countless centuries that these trees have been represented in the forests of past geological times, and the vast areas that they have ranged over during those ages. As far as is known at the present time none have been found in deposits of Cretaceous age and the linden line is therefore less ancient than that of the majority of our forest trees, unless possibly the unknown expanse of Asia has Cretaceous lindens hidden somewhere in its bosom.

The oldest known lindens are found in the Eocene, or early Tertiary. In the rocks of this age four or five different species have been discovered and while this number is small the localities where they are found point rather unmistakably to the region where the linden stock probably originated. None occur south of latitude 40° and two come from north of latitude 60°.

One of the latter was found above 80° north latitude, which is as near the North Pole as the remains of any trees have been discovered.

This species, *Tilia Malmgreni*, a leaf of which is shown on the accompanying plate, was described by Heer and had typical broad leaves about the size of those of the existing European lime. It has been recorded from rocks which are probably late Eocene in age in Grinnell Land, Spitzbergen and Iceland, where it is associated with volcanic rocks (basalts) that seem to have characterized the earlier Tertiary throughout the North Temperate and the Arctic regions. It affords perhaps the most striking illustration of the different climate and floral distribution that is disclosed by a review of the ancestors of any of our trees, and it is almost impossible for us to picture forests of broad leaved temperate trees covering the present perpetually ice clad wastes of Grinnell Land, and flourishing where the winter's night lasted for six months.

A second Eocene species occurs in the Kenai region of Alaska and a third on Sachalen Island off the Asiatic coast immediately north of Japan. A fourth has been found in the early Eocene of Montana. This Eocene distribution would seem to indicate that the linden stock originated somewhere in the far north, but whether actually in the Polar region or in northern North America or northern Asia it is impossible to say. The Montana species is somewhat older than the other known Eocene forms and this may mean that it is nearer than the others to the place of origin of the genus, or it may be due simply to accidents of preservation or of discovery since earlier forms in other areas may not have been preserved at all or may still be awaiting discovery in the rocks.

No Oliogocene lindens are known and this must be ascribed to the reasons mentioned at the close of the preceding paragraph since in the succeeding Miocene times there was a great display of a variety of lindens. They are found at this time from the base to the top of the Miocene deposits of Europe, where plant beds of this age are much more abundant than they are in either North America or Asia. At least fourteen different Miocene species are known and their remains include several of the characteristic and curiously bracteate fruits as well as a variety of leaves. The lindens are especially abundant and varied in the late Miocene of southern Europe along the shores of the expanding Mediterranean sea of that time, and in the Pyrenees, the foothills of the Apennines and in the mountains of Transylvania, Styria and Bohemia. The fruit of one of these late Miocene species found near Vienna in Austria and named *Tilia vindobonensis* from the old Roman name of Vienna is shown on the accompanying plate.

The Miocene records in North America are scanty but the genus was still represented in the Rocky Mountain region having been found in deposits of this age in the Yellowstone Park and in the lake basin at Florissant, Colorado, both of which localities are now separated by several hundreds of miles of treeless plains country from the westernmost outposts of the existing species in the river valleys of eastern Kansas and Nebraska.

The known Pliocene lindens, owing to the rarity of plant beds of this age in North America, are confined to Eurasia, although the genus was undoubtedly present in North America during the Pliocene since it is found in the deposits of the immediately preceding and succeeding times. There are four Pliocene forms recorded from Europe where they are found in variety and abundance in the Auvergne region of France, and in northern Italy.

Although the Pleistocene records of the linden are not numerous nevertheless lindens are found in deposits of this age in both North America and Europe. Fruits of two different forms occur in Interglacial beds in Germany and *Tilia* wood is recorded from the lower Pleistocene of Holland. The leaves of the still existing basswood, which is the most wide ranging of our American lindens have been found in the Interglacial beds of the Don Valley near Toronto, and another form, or perhaps the same species under another name is found in the late Pleistocene terrace deposits of the Delaware River in southern New Jersey. Undoubtedly other of the existing species were already in existence and it would not be at all surprising if the southern basswood were discovered in the similar river terraces of our southern states.

# TEMPERATURES OF SMALL FRUITS WHEN PICKED

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It has been known for over a century ((6), p. 538) that certain plant parts may reach a temperature markedly above that of the air. Accurate observations on this temperature relation have been made by several investigators.[1] There seems to be no record in available literature, however, of the easily observed fact that many small fruits attain on clear days, largely through insolation, a temperature much higher than that of the air. This condition was first noted in cranberries (*Vaccinium macrocarpon* Ait.[2] during the fall of 1916. As opportunity offered in connection with other work during the summer of 1917, the writers have made observations on the temperature of various small fruits in relation to air temperature at picking time. The data thus accumulated are thought to be of some botanical interest. They are of particular significance, also, in relation to the decay of these fruits in transit and on the market. This relation does not seem to have been applied generally to horticultural practice; however, the fact that small fruits, notably strawberries, keep better if picked when cold than if picked later in the day, when warm, has been demonstrated by the writers (10).[3]

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[1] The studies of Ehlers on leaves of *Pinus* may be cited as a recent example of this type of work. His paper (3) gives a review of the more important publications on the subject, with special reference to those dealing with leaf temperature. Some of the more general papers are mentioned by Pfeffer (7, vol. 3, p. 378–381). No attempt at a complete bibliography is made in the present paper.

[2] The nomenclature used is in general that of Gray's Manual of Botany, Seventh Edition, 1908.

[3] Powell (Powell, G. Harold, Bur. Pl. Ind. Bul. no. 40, 1903) calls attention to the fact that peaches picked and loaded into cars during the middle of the day are warmer, and carry to market less well, than those picked early in the morning. He does not note, however, that in the middle of the day the fruit is actually warmer than the air.

## METHODS

The method of making temperature observations was as follows: The fruit was picked in the usual manner into the standard container used for the sale of the fruit, generally a quart basket, and the temperature ascertained by thrusting the bulb of a chemical thermometer into the mass of fruit near the center of the basket. The temperature thus obtained was of course not the temperature of the berries themselves, but of the outside surface of the berries and the air among the berries. In other words it was approximately the average temperature of the mass of berries and air which goes into the crate when it is packed. Air temperature was recorded from a thermometer kept in the shade near by.

More accurate data would, of course, have been obtained by more elaborate methods, but that chosen could be used with convenience in practically the same way on a variety of fruits.

## RESULTS OF OBSERVATION

The results of the observations made by this method are given in table 1. The data are arranged in the order in which they were taken, which is approximately that in which the fruits ripen, though this is modified somewhat by the fact that observations were made in widely separated localities. In some cases information of interest was obtained which it is not practicable to include in the table. This is given in the text in the same order.

## STRAWBERRIES

During the work on strawberries (*Fragaria* sp.) numerous observations were made on the temperatures inside the berries. The temperature was determined by thrusting the bulb of a small thermometer into the tissues of the berry so that the bulb was completely covered. This method of determining temperature is open to the criticism that the berries were wounded and wounding has been demonstrated by Richards (8) and others to cause an increase in the activity of respiration and also in the

TABLE 1

*Temperatures of small fruits when picked*

| FRUIT | LOCALITY AND DATE | TEMPERATURE | TIME OF OBSERVATION* | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6.00 | 7.00 | 8.00 | 9.00 | 10.00 | 11.00 | 12.00 | 1.00 | 2.00 | 3.00 | 4.00 | 5.00 | 6.00 | 7.00 |
| | | | °C. | °C. | °C. | °C. | °C. | °C. | °C. | °C. | °C. | °C. | °C. | °C. | °C. | °C |
| Strawberries | Hammond, La., April 18, 1917 | Berries | | | 24.5 | 28.5 | 31.0 | 31.0 | 32.0 | | 30.5 | | | | | |
| | | Air | | | 24.5 | 25.5 | 28.0 | 28.0 | 27.5 | | 28.0 | | | | | |
| | | Difference | | | 0 | 3.0 | 3.0 | 3.0 | 4.5 | | 2.5 | | | | | |
| Strawberries | Hammond, La., April 23, 1917 | Berries | 15 | | 23.5 | | 29.5 | | 31.0 | | 35.0 | | 32.5 | | 21.0 | |
| | | Air | 16 | | 23.5 | | 25.0 | | 26.0 | | 29.0 | | 30.5 | | 19.0 | |
| | | Difference | −1 | | 0 | | 4.5 | | 5.0 | | 6.0 | | 2.0 | | 2.0 | |
| Strawberries | Monett, Mo., May 23, 1917 | Berries | 7 | 8.0 | 11.5 | 17.0 | 20.0 | 23.5 | 25.0 | 25.0 | 26.0 | 28.0 | 26.0 | 22.0 | 17.0 | |
| | | Air | 7 | 7.0 | 10.0 | 10.5 | 12.0 | 17.0 | 15.5 | 17.0 | 17.0 | 19.0 | 17.5 | 16.5 | 16.0 | |
| | | Difference | 0 | 1.0 | 1.5 | 6.5 | 8.0 | 6.5 | 9.5 | 8.0 | 9.0 | 9.0 | 8.5 | 5.5 | 1.0 | |
| Green gooseberries | Arlington Farm, Va., June 16, 1917 | Berries | 8 | 12.0 | | 20.5 | 21.5 | 22.0 | 22.0 | 23.5 | 23.0 | 23.5 | | 19.0 | 16.5 | |
| | | Air | 8 | 12.0 | | 16.0 | 17.0 | 18.0 | 19.5 | 20.0 | 20.5 | 20.5 | | 16.5 | 16.5 | |
| | | Difference | 0 | 0 | | 4.5 | 4.5 | 4.0 | 2.5 | 3.5 | 2.5 | 3.0 | | 2.5 | 0 | |
| Currant (Red) | Milton, N. Y., July 13, 1917 | Berries | | | 24.0 | 28.0 | 29.5 | 31.5 | 33.5 | 31.5 | 31.5 | 28.0 | 26.5 | 25.0 | 25.0 | |
| | | Air | | | 22.5 | 23.0 | 24.5 | 25.0 | 25.0 | 26.5 | 26.5 | 26.0 | 25.5 | 25.0 | 25.0 | |
| | | Difference | | | 1.5 | 5.0 | 5.0 | 6.5 | 8.5 | 5.0 | 5.0 | 2.0 | 1.0 | 0 | 0 | |
| Blueberries | White's Bog, N. J., July 17–18, 1917 | Berries | 22 | 27.0 | 27.0 | 29.0 | 30.0 | 31.0 | 40.0 | 37.0 | 39.5 | 37.0 | 34.0 | 31.5 | 28.0 | 26 |
| | | Air | 22 | 25.0 | 26.0 | 27.0 | 28.0 | 28.0 | 31.0 | 31.0 | 31.0 | 33.0 | 33.0 | 29.0 | 27.0 | 26 |
| | | Difference | 0 | 2.0 | 1.0 | 2.0 | 2.0 | 3.0 | 9.0 | 6.0 | 8.5 | 4.0 | 1.0 | 2.5 | 1 | 0 |
| Cranberries (Howes) | Wareham, Mass., October 3, 1916 | Berries | | 9.5 | 17.0 | 18.0 | 24.0 | 26.0 | 27.5 | | 24.0 | 23.5 | | | | |
| | | Air | | 9.5 | 16.0 | 17.0 | 17.5 | 21.0 | 22.0 | | 21.5 | 21.0 | | | | |
| | | Difference | | 0 | 1.0 | 1.0 | 6.5 | 5.0 | 5.5 | | 2.5 | 2.5 | | | | |

* Cloudy 8.00 a.m.–11.00 a.m.

production of heat in certain plant parts. In the investigations of Richards, however, the increases in temperature due to wounding were relatively small, i.e., 0.20°C. to 1.2°C. ((8), p. 38–40). It is, then, hardly conceivable that any large part of the difference in temperature was due to the so-called "wound stimulus." In any case the relations between the berries in different locations and at different times of day, as well as that between green and ripe fruit, are significant.

Table 2, giving the observations at Hammond, Louisiana, April 23, 1917, shows the relation of the temperature of the inside of the strawberry to that of the air just outside of and between the berries in the box, and these data have been substantiated by other observations elsewhere.

TABLE 2

*Temperatures of strawberries in degrees Centigrade*

| TIME | AIR TEMPERATURE | TEMPERATURE OF BERRIES IN THE BOX | TEMPERATURE INSIDE OF BERRIES | |
|---|---|---|---|---|
| | | | In shade | In sun |
| 6.00 a.m. | 16.0 | 15.0 | 13.0 | 17.0 |
| 8.00 a.m. | 23.5 | 23.5 | 23.0 | 33.0 |
| 10.00 a.m. | 25.0 | 29.5 | 29.0 | 38–42.0 |
| 12.00 m. | 26.0 | 31.0 | 30.0 | 36.5 |
| 2.00 p.m. | 29.0 | 35.0 | 34.5 | 39–43.5 |
| 4.00 p.m. | 30.5 | 32.5 | 30.5 | 36–39.5 |
| 6.45 p.m. | 19.0 | | 21.0 | |

The temperature of individual berries in the sun varies widely with the exposure of the berries. The temperatures given in table 2 are for ripe berries, but green berries showed similar variation. For example, green berries in the same fieldshowed at 2 p.m. on the same day, a temperature of 34°C. in the shade and temperature ranging from 39°C. to 45°C. in the sun.[4]

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[4] In connection with these notes on the temperature of strawberry fruits the observations of Seeley on the temperature of strawberry leaves should be noted. (Seeley, D. A. The relation between temperature and crops. Nineteenth Report Michigan Academy of Science, 167–196, 1917.) Summarizing the results of 304 simultaneous observations of strawberry leaf and air temperature made at midday in 1915 and 1916 at East Lansing, Michigan, he says,

### CURRANTS AND GOOSEBERRIES

In both currants and gooseberries (*Ribes* spp.) it was observed that the temperature of the fruits on the bushes was not nearly so high as was reached by the same fruits when spread out in the sun on a paper.

Currants picked from bushes in almost complete shade at Milton, N. Y., on July 13, 1917, at 9 a.m. were found to have a temperature of 23.5°C., while those picked from bushes in full sunlight had a temperature of 29.5°C. After exposure to the sun for two hours on a paper, both lots showed a temperature of 38°C., whereas berries freshly gathered from bushes in full sunlight had a temperature of 31.5°C. Green gooseberries exposed to direct sunlight for two hours at Arlington Experiment Farm, Virginia, reached a temperature of 34°C., while those freshly picked had a temperature of 23.5°C. Air temperature was 20°C. The difference was apparently largely due to the fact that the berries on the bushes were somewhat shaded. In addition, those exposed to the sun were placed near the ground where air currents were slower and loss of heat by convection was probably thus reduced.

### RASPBERRIES

The data on raspberries (*Rubus* sp.) are so fragmentary that they are not worth tabulating. They do, however, indicate that the same relation holds for these as for the other small fruits. Observations on black raspberries (*Rubus* sp.) and yellow raspberries (*Rubus* sp.) were made at Vienna, Virginia, July 20, 1917. The day was partly cloudy and is recorded by the Weather Bureau as giving 41% sunshine at Washington, the nearest Weather Bureau station, about 10 miles distant.

The temperature of a box of black raspberries picked at 1

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(p. 193) "In round numbers the average difference between the plant and air temperature in full sunshine was 15° F.; in partial sunlight, due to thin clouds or intermittent cloudiness, it was 10° F. and less than 1° F. when the sky was thickly overcast, so that the sun's disk was invisible." One instance is cited in which the leaf temperature was 36° F. above that of the air.

p.m. was 32°C., and of a box of yellow raspberries picked at the same time on adjacent bushes of somewhat more luxurious growth was 31°C. The air temperature at this time was 27°C.

## CRANBERRIES

Observations on cranberries were made by one of the writers while working in cooperation with Dr. H. J. Franklin, Superintendent of the Massachusetts Cranberry Station at East Wareham, and were published by Dr. Franklin in his Annual Report for 1916 (5). These data first called attention to the fact that the temperature of berries when picked is frequently above that of the air, and were the starting point of the observations presented in the present paper.

## RELATION OF TEMPERATURE TO SUNSHINE

The facts indicate that the higher temperature of the fruits is largely due to the absorption of radiant energy. In general the difference between the temperature of the berries and that of the surrounding air was greatest when the sun was highest, less in the forenoon and afternoon, and practically zero at night and on cloudy days (see table 1). Exceptions occurred in those cases when the temperature of the air dropped rapidly and that of the fruit had not yet adjusted itself. No constant difference between the temperature of the berries and that of the surrounding air, at night or on cloudy days, was ascertainable by the methods used.[5] The temperature of berries borne in the shade was much lower when picked than was that of similar berries exposed to the sun. Currants and gooseberries which had been exposed to the direct rays of the sun for some time acquired a higher temperature than those which were on the bushes in partial shade.

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[5] This does not mean that berries when not exposed to the sun are always at exactly the same temperature as the air. Their temperature is undoubtedly somewhat affected by respiration and the temperature of the berries ordinarily lags somewhat as that of the air changes. Especially in the morning, when the air is becoming rapidly warmer, there is often a period when the berries are markedly below air temperature, sometimes 4 to 5 degrees C. This period is longest on mornings when the berries are wet with dew.

The possibility should not be ignored that a small part of the observed rise in temperature may be due to heat arising from respiration and that this heat may increase with rise in air temperature ( (7), p. 367). The amount of heat developed by the respiration of ripe fruits was, however, found by Dutrochet ( (2), p. 82), who worked with pears (*Pyrus communis* L.) plums (*Prunus* sp.), peaches (*Prunus persica* L. Stokes) and *Ribes Uva-crispa,* to be sufficient to raise their temperature only from 0.06°C. to 0.08°C. Rodewald ( (9), pp. 296 and 342), working with ripe apples, found that the amount of heat arising from respiration was slight compared with that necessary to produce such differences in temperature as those cited in the present paper.

On the other hand rise of temperature due to insolation has been observed in some other plants to be much greater than that reported by the writers even in the strawberry. Askenasy ( (1), p. 441) observed that the temperature of the leaves of *Sempervivum* exposed to the sun may attain temperatures of 43.7°C. to 41.2°C. when the temperature of the air is only 31°C., while Ewart (4) records temperatures of 45°C. to 50°C. in the leaves of several tropical plants.

## COLOR OF FRUIT IN RELATION TO TEMPERATURE

So far as the present observations extend, the color of the fruit does not seem to materially affect the temperature reached at a given time. No constant difference could be noted between red (*i.e.,* ripe) strawberries and green or white (unripe) ones of the same variety in the same field. No difference could be found between red and white currants. Although repeated tests were made comparing the temperature of red (ripe) cranberries of the Early Black variety with that of green or white (unripe) cranberries of the Late Howe variety gathered at the same time, no constant difference could be observed.

Although it is probably true that fruits of certain colors absorb more heat than others, the loss of heat is so rapid that the excess of heat absorbed over that lost is possibly about the same in all.

That fruits of all colors absorb considerable amounts of radiant energy is highly probable if we accept Pfeffer's ((7), p. 330) estimate that green and other colored leaves may absorb from 50% to 90% of the sun's rays falling upon them.

## SUMMARY

Observations on a variety of small fruits show that on clear days they usually have a temperature considerably above that of the air.

This rise in temperature seems to be mostly due to the absorption of radiant energy from the sun; no such difference was found at night or on cloudy days, and berries in the shade are uniformly cooler than those in the sun.

No constant difference in the temperatures of fruits of the same variety but of different colors has been demonstrated.

## LITERATURE CITED

(1) ASKENASY, E.: Ueber die Temperatur welche Pflanzen im Sonnenlicht annehmen. Bot. Ztg. **33**: 441–444. 1875.

(2) DUTROCHET, M.: Recherches sur la chaleur propre des êtres vivans à basse température. Ann. Sci. Nat. Bot., ser. 2, **13**: 5–49, 65–85. 1840.

(3) EHLERS, J. H.: The temperature of leaves of *Pinus* in winter. Amer. Jour. Bot. **2**: 32–70, 4 fig., bibliography, 1915.

(4) EWART, A. J.: Effects of tropical insolation. Ann. Bot. **11**: 439–480. 1897.

(5) FRANKLIN, H. J.: Report of the Cranberry Substation (Mass.) for 1916. Mass. Agri. Exp. Sta., Bull. No. 180. Nov. 1917.

(6) LAMARCK, J. B. P. DE M DE.: Flore françoise . . . . t. 3, Paris. 1778.

(7) PFEFFER, W.: Physiology of plants . . . . v. 3, Oxford (Eng.). 1906.

(8) RICHARDS, H. M.: Evolution of heat by wounded plants. Ann. Bot., **11**: 29–63, 1897.

(9) RODEWALD, H.: Quantitative Untersuchungen über die Wärme und Kohlensaüreabgabe athmender Pflanzentheile. Jahrb. Wiss. Bot., **8**: 263–245. 1887.

(10) STEVENS, N. E., AND WILCOX, R. B.: Further studies on rots of strawberry fruits. U. S. Dept. Agr. Bul. 686. June 24, 1918.

# BOOKS AND CURRENT LITERATURE

Vegetation of Northern Bombay.—An interesting account of the plant associations of an area in the northern part of the Bombay Presidency, India, has been contributed by Saxton and Sedgwick.[1] Since western India has been hitherto ecologically quite unknown an extended review seems justified. The original paper is not readily accessible and would easily escape notice of ecologists.

The area reported on is roughly bounded on the west by a line connecting Kharaghoda, located on an arm of the Arabian Sea, with Ahmedábad, 55 miles inland to the southeast. From this line a strip extending 70 miles to the east was studied. The northern boundary of the district is 5 miles north of the Tropic of Cancer.

The soil is chiefly sand in the western part, without rocks. Rivers and streams have cut 50 to 100 feet below the general level of the plateau. Farther east there are stony hills but the authors did not study these fully. Limited areas in sandy districts consist of (a) upland humus soil, (b) salt-marsh encrusted loam, (c) clay. There are numerous "water-holes," large and small, especially in the upland humus areas and in the clay. Artificial irrigation is practiced in much of the territory.

The climate is severe. It is characterized by intense heat, and a low annual rainfall. Precipitation comes almost entirely during the southwest monsoon of June, July and August. At that time the soil is thoroughly soaked and soggy and humidity is high. During the long rainless period the soil and air become progressively drier. The average rainfall for the entire district is about 30 inches, but at Kharaghoda it is only 24 inches. The highest maximum temperature recorded is 120° F. at Ahmedabad, which is considerably lower than in the Punjab, but because of the very warm winters the mean annual temperature is one of the highest in India. Frost occurs about once in ten years.

The authors state that fully 95 per cent of the vegetation is to be classed as psilophytic (savanna) or psammophytic (of sand and gravel). "Warming's description exactly applies to those parts of the Indian plains which are untouched by the northeast monsoon or the winter storms. . . . Accepting savanna as the type of our formations we find the following transitions (types) which result solely from edaphic causes."

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[1] Saxton, W. T., and Sedgwick, L. J. Plants of Northern Gujaret. Records of the Botanical Survey of India **6**: 203-323. 1918.

1. Xerophytic Woodland develops on hillsides in the northeastern part of the area. It is a fairly close growth of deciduous trees in which the characteristic species is *Terminalia tomentosa* (Combretaceæ) with which are associated *Boswellia serrata* (Burseraceæ), *Phyllanthus emblica* (Euphorbiaceæ), *Bassia latifolia* (Sapotaceæ), *Aegle marmelos* (Rutaceæ) and *Tectona grandis* (Verbenaceæ), the teak. In more level places with deeper soil the forest gives way to a grass association with interspersed trees of *Terminalia*, *Bassa*, etc.

2. Savanna Woodland is found on rocky soil. It is a more open growth than the association just considered. The same trees occur, together with various others, such as species of *Sterculia*, *Diospiros* and *Anogeissus* (Combretaceæ). There are a number of shrubs but none abundant except *Helicteres isora* (Sterculiaceæ)

3. Thorn Savanna is a highly xerophytic association on gravel and on compacted sand where water does not easily penetrate. The characteristic plants are thorny shrubs and small, thorny trees. The authors characterize it as a "highly aggressive" community. Species of *Zizyphus* (Rhamnaceæ) dominate large stretches of country. Abandoned fields often grow up to thorn savanna in which *Capparis aphylla* is the chief species, or to an association of *Zizyphus rotundifolia*, *Cassia auriculata* and *Calotropis procera* (Asclepiadaceæ). Common lianas of the thorn savanna are *Asparagus racemosa*, *Leptadenia reticulata* (Asclepiadaceæ) and *Cocculus villosa* (Menispermaceæ). Undergrowth is composed of low herbage, especially *Lepidagathis trinervis* (Acanthaceæ) and *Convolvulus pluricaulis*. Grasses belong to the genera *Aristida*, *Andropogon*, *Tragus*, *Gracilea*, *Chloris*, etc. The first two are of tuft form (cf. "bunch grasses" of our western plains).

4. Butea Savanna develops on sand that has considerable humus. It is dominated by a small tree, *Butea frondosa* (Leguminosæ), with occasional scattered individuals of such large trees as *Bassia latifolia* and *Bombax malabaricum*. Common undershrubs are *Cassia auriculata* and *Triumfetta rotundifolia* (Tiliaceæ). Grasses are the same as in other savannas. The authors remark that the association demands further ecological study. While they do not say so it may be judged that the Butea Savanna, in its various modifications, represents the climatic climax plant community. A modified type of the association

is represented on clay outcrops where the *Butea* continues to dominate but all large trees are absent; Mimosaceous shrubs and climbers are abundant. Open areas of grassland, locally known as "birs," are common throughout the district studied with the grasses already named and in addition *Ischæmum rugosum*, *Iseilema wightii* and others. *Anthistria ciliata*, one of these, is probably the best fodder in India. The authors state that fire is of rare occurrence; hence it would seem (to the reviewer) that these open stretches are not to be accounted for by fire as are, for example, the patanas of Ceylon but are to be thought of as natural open savanna. Indeed the authors state that "these grasslands are nowhere treeless."

5. Sand Savanna is particularly difficult to study because the area where it is present has been densely populated for a very long period. It is often quite uncertain how far trees are planted and how far they are a part of the natural vegetation. The authors give extensive lists of trees, shrubs and herbs for the savanna on sandy soil, the majority of which occur also in other types of savanna. Nearly all of the plants are inactive during the dry season except when under the influence of artificial irrigation. As the climate of the sandy area is drier than elsewhere the conditions for plant life are especially severe and well-marked xerophytism is the rule.

6. Sand Associations of Herbs and Low Shrubs (Psammophytes) develop on dunes and on hills of soft sand (what we in America would call "sand hills") and also on upper river terraces. Dunes and sand hills are "dominated either by *Saccharum munja* or by *Crotalaria burhia* and associated with these are *Cyperus niveus*, *C. arenarius*, *C. conglomeratus*, and many other members of the sand savanna." On higher river terraces "the usual association is *Acacia jacquemontii*, *Leptadenia spartium* and *Cassia auriculata*." The authors suggest that the psammophytic associations "may with further study have to be amalgamated with sand savanna" but it appears (to the reviewer) that they form an edaphic climax likely to persist indefinitely as, for example, the pine barrens of New Jersey.

Hydrophytes and Helophytes of the district are confined to waterholes, reservoirs and rivers. Among the former the most abundant plants are *Nymphæa lotus*, *Ipomœa aquatica*, *Hydrilla verticillata*, *Vallisneria spiralis*, *Zannichellia palustris* and *Potamogeton pectinatus* together with species of *Azolla*, *Chara*, *Nitella* and smaller algae. Swamp plants are represented by a number of well-marked associations surrounding permanent and temporary bodies of water. *Typha* *angustata* dominates one association, *Andropogon squarrosus* another; while still other associations are those of *Cyperus laevigatus*, *Herpestis monniera*, *Sporobolus tremulus*, *Eleocharis plantiganea*. A "dried mud formation" exists around water-holes where there is much tramping of cattle and wallowing of buffaloes. The plants are mostly prostrate with long tap roots, and include species of *Polygonum*, *Mollugo*, *Coldenia* (Boraginaceæ), *Euphorbia*, *Gnaphalium*, *Heliotropium* and *Trigonella*.

Halophytic Associations, the authors state, have been only inadequately studied. There is a sort of halophytic savanna near the coast in which the most prominent shrubs are *Indigofera pauciflora*, an *Acacia*, and *Sueda nudiflora*. Grasses fill in the interspaces. Areas of halophytic semi-desert occur inland near Prantij where, during the dry period there is little to be seen but a white efflorescence on the soil. During the monsoon and early autumn a weak growth develops of *Sporobolus orientalis*, *Chloris villosa*, *Eleusine aegyptica*, *Diplachne fusca* and *Fimbrystilis spathacea*.

Lithophytes are represented by an association on the city walls of Ahmedabad comprising *Lindbergia urticæfolia* (Scrophulariaceæ), *Linaria ramosissima*, and the following grasses: *Eragrostis tenella*, *Arthaxon microphyllus*, *Aristida adsenscionis*, and *Andropogon contortus*.

Mesophytic Associations are met with only in irrigated situations and are chiefly "weeds of cultivation" and "hedge plants." There are two distinct floras, one developing in the period of the monsoon, the other in winter. This latter has a number of species familiar to botanists of temperate regions: *Chenopodium album*, *Asphodelus tenuifolius*, *Gynandropsis pentaphylla*, *Melilotus indica*, *Datura fatsuosa*, *Argemone mexicana*, *Andgallis arvensis*, *Foeniculum vulgare*, *Saponaria vaccaria*, *Convolvulus arvensis*.

The total number of species and varieties of flowering plants recognized in the area is 614. The paucity of species is, of course, an expression of the unfavorable climatic and edaphic conditions. Grasses and sedges comprise about one-fourth of the total flora, being represented by 103 and 45 species respectively. It is interesting to note that of the sedges the largest genus is *Cyperus* with 20 species while *Carex* is entirely absent. *Panicum*, *Eragrostis* and *Andropogon* are the large genera of grasses; *Poa* is unrepresented. Among dicotyledons the large families with the number of species in each are as follows: Leguminosæ (83), Convolvulaceæ (24), Compositæ (23), Euphorbiaceæ (23), Acanthaceæ (21), Malvaceæ (20), Scrophulariaceæ (13), Amarantaceæ (13), Liliaceæ (13), Cucurbitaceæ (11), Labiatæ (11), Asclepiadaceæ (10).

It is somewhat disappointing that the authors have given us no half-tone illustrations of the vegetation. Botanists familiar with eastern Java or norther Ceylon will, however, be able to picture to themselves something of the appearance of the plant associations described. —Francis Ramaley.

## NOTES AND COMMENT

A recently issued Farmer's Bulletin of the Department of Agriculture (No. 962) gives an extended account of the velvet bean, which has rapidly sprung into a place of great importance as a forage plant in the Gulf states. It is similar to the running varieties of cow peas but of coarser habit, and the several cultivated strains are derived from *Mucuna utilis*, while the common name alludes to the extremely hairy pod. After fifteen years of limited cultivation in Florida it is now grown extensively in Alabama, Georgia and Mississippi and to some extent in the adjacent states, the extension of its cultivation being due to the development of early-ripening strains. The crop of 1916 was four times as great as that of 1915, and in 1917 the total crop was again quadrupled, amounting to about five million acres. The yield ranges from two to four tons per acre, or more, and the vines and beans are mixed with corn stalks to form an ensilage which has proved to be so valuable as to serve as a great stimulus to stock growing in the southeastern states. In addition to the publication mentioned there is further information on the velvet bean, particularly on its feeding value, in Bulletins 104, 192 and 198 of the Alabama Experiment Station.

The seventeenth volume of the Memoirs of the Torrey Botanical Club is devoted to the papers that were presented at the Semi-Centennial Anniversary of the Club on October 18, 19 and 20, 1917. An historical sketch of the Club and the reminiscences of several of its long-standing members open the volume, followed by twenty-seven scientific papers. Among the longer papers may be mentioned: The Trimorphism and Insect Visitors of *Pontederia*, by Tracy E. Hazen; Statistical Studies in *Cichorium*, by A. B. Stout and Helene M. Boas; the Osmotic Concentration of Tissue Fluids of Desert Loranthaceae, by J. Arthur Harris; The Vegetation of the Hempstead Plains, by Roland M. Harper; The Uredinales of Cuba, by J. C. Arthur and J. R. Johnston; and The Evolution of Cell Types and Contact Pressure Responses in *Pediastrum*, by R. A. Harper.

Professor C. Conzatti has published an illustrated paper on the vegetation and flora of the southern coast of Oaxaca, in the Boletin de la

Direccion de Estudios Biologicos, of the City of Mexico. A brief sketch of the plant life is given in the form of an itinerary of the author's journey from the mountains of the interior to the coast, through a region which is botanically little known. A list is given of the localities visited and the plants collected.

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# The Plant World

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AUGUST, 1918

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# NOTES ON DUNE VEGETATION AT SAN FRANCISCO, CALIFORNIA

FRANCIS RAMALEY

*University of Colorado, Boulder, Colorado*

The dunes[1] here considered extend south from Golden Gate Park[2] about 5 km. and inward from the ocean 2 to 4 km. An automobile highway parallels the ocean shore at the west but has had no influence upon the dunes or their vegetation. Prevailing winds are west-south-west; winds from other directions seem to be of no consequence.

Conditions for plant life at San Francisco are severe. As is well known, the climate exhibits a rainy and a dry season, the rains being confined to winter and early spring. The rest of the year is without precipitation. Soils dry out, and only xerophytic plants are to be found most of the year except in ravines, on north slopes or in other favored places. The plants of dunes and sand hills are, of course, subject to this unfavorable climate, also to austere soil conditions. The sand of the dunes is light and even in very moderate winds is continually being blown along and can be seen rising 1 to 2 dm. at almost any time.[3]

The severity of conditions is shown by the large areas, often 500 meters square, with no vegetation whatever. Then there are still more extensive tracts with only occasional mounds

---

[1] The writer became acquainted with these dunes while giving courses in the summer session of the University of California, June–August, 1917. At the close of the session a number of days were spent at San Francisco in continuous field study.

[2] Visitors to San Francisco can reach the dunes by street car, taking line 7, 12 or 17 from the Ferry Building at the foot of Market Street, riding to near the end of the line.

[3] A chemical analysis of the dune sand at San Francisco is given by Olsson-Seffer in his article on Relation of soil and vegetation on sandy sea shores, Bot. Gaz. **47**: 85–126. 1909.

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crowned with plants. In low places, especially in the shelter of high dunes, a fairly close plant community may occur, but elsewhere there is always much bare ground.

Such printed information[4] as is available suggests that dunes elsewhere along the Pacific Coast of the United States bear a certain, often remote, resemblance in their vegetation to the dunes at San Francisco. No extensive lists of plants have been published, however, nor have the pioneers and later comers been clearly distinghished. The species represented at San Francisco, and to a large extent the genera, are different from those of the Lake Michigan[5] dunes or the dunes of Denmark[6] and other European coasts.

## TYPICAL DUNE VEGETATION

The pioneer plants are chiefly the sand verbena (*Abronia latifolia*) and a low, spreading, Ambrosia-like herb, *Franseria chamissonis*. Other plants are, however, responsible at times for holding down mounds of greater or less size, as the sand strawberry (*Fragaria chilensis*), dune tansy (*Tanacetum camphoratum*), sand primrose (*Oenothera cheiranthifolia*), the wild cucumber (*Echinocystis fabacea*), and, close to the ocean, the ice plant (*Mesembryanthemum aequilaterale*).

Marram grass (*Ammophila arenaria*) was introduced about forty years ago and has been extensively planted since. In a few places, close to the beach, it has become well established but over the greater part of the dunes here described not a culm of it is to be seen. A number of "town lots" have been carefully planted to marram grass but without brilliant results.[7]

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[4] Crouch, Edward B., Notes on the ecology of sand-dune plants. Plant World, **17**: 204–208. 1914.

Davy, Joseph Burtt, Stock ranges of northwestern California. Bureau of Plant Industry, Bull 12. 1902.

House, H. D., The sand dunes of Coos Bay, Oregon. Plant World, **17**: 238–243. 1914.

Kellogg, F. B., Sand-dune reclamation of the coast of northern California and southern Oregon. Proc. Soc. American Foresters, No. 1, 41–64. 1915.

Olsson-Šeffer, Pehr, *op. cit.*

[5] Cowles, H. C., Ecological relations of the vegetation of the sand dunes of Lake Michigan. Bot. Gaz. **27**: 95–117, 167–202, 281–308, 361–391. 1899.

[6] Warming, Eug., Oecology of Plants (English Edition, Oxford), 265–272. 1909.

When one of the pioneer plants such as *Franseria* or *Abronia* is well started, other species come in and occupy some of the ground thus held in place. The second comers are chiefly those already named as occasional pioneers. Later arrivals are the yarrow, pearly everlasting, painted cup, false dandelion, lupines, *Baccharis, Ericameria*, California poppy, *Eriogonum, Eriophyllum, Artemisia, Polygonum paronychia* and others (see systematic list).

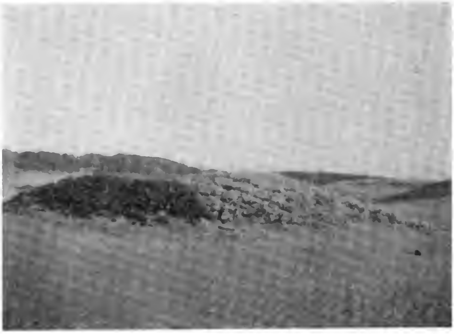

Fig. 1. Strawberry (dark) and *Franseria* (light) on a low mound of the dune area.

### *Shrubby Plants*

Shrubby plants of the dunes are all low. Even willows do not become tall except in depressions. A few of these are as much as 4 meters in height but most are only 1 or 2 meters. The yellow lupine (*Lupinus arboreus*) is a meter or more tall in protected places, but on exposed dunes it is often only 2 to 4 dm. Other shrubs of importance, mostly low-growing, are *Lupinus chamissonis*, a blue-flowered species with silvery foliage, *Rhamnus californica*, with dark-green entire leaves, *Baccharis pilularis*, a small-leaved composite often important as a constituent of chaparral on mountain sides, and *Ericameria ericoides*, a heath-like composite. Two undershrubs are *Eriophyllum* and *Artemisia*.

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[7] Marram grass has served most successfully to hold the sand in various places about San Francisco. Indeed a large part of Golden Gate Park is a reclaimed dune area. But continued care over a number of years is necessary for establishment of a good stand.

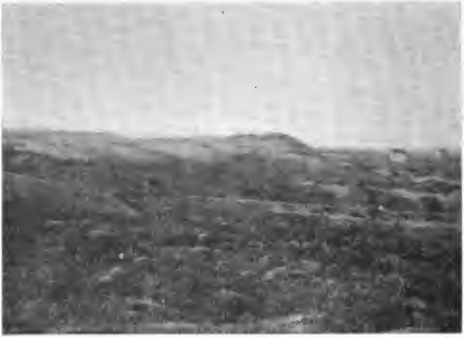

Fig. 2. General dune landscape. The vegetation in the protected area of the foreground is soon to be destroyed by the advancing dunes.

### *Plants of Low Places*

In low places where vegetation is well established willow dominates and with it occur, in addition to plants already named, *Juncus*, *Eleocharis*, *Scrophularia*, *Cirsium* and *Mimulus*. One or more xerophytic mosses may be found on north slopes. They are, however, of slight ecological significance. Weeds occur sparingly in low areas well covered with vegetation and adjacent to traveled thoroughfares. Species of the following genera were noted: *Bromus, Festuca, Chætochloa, Plantago, Lactuca, Erigeron, Solanum.* The greater extent of the dunes is, however, without foreign plants of any kind.

### *Annuals*

Very few annual plants were to be seen at the time of this study (July-August, 1917) since such as occur in the area complete their growth during the spring. The following native annuals were, however, noted: *Epilobium minutum, Epilobium paniculatum, Chorizanthe pungens, Plantago patagonica californica.* Besides these native plants a number of the weeds mentioned above are annuals, but as already suggested they are of little importance and are almost entirely confined to low ground with a well-established plant cover or else occur in the vicinity of dwellings or along roads.

### *Plants of Sheltered Places*

Some plants are locally frequent, or even abundant, in sheltered stations, though the soil is not especially moist, viz.: *Eriogonum, Pentacæna, Cirsium, Eschscholtzia, Eriophyllum, Polygonum, Castilleia.* In the sheltered nooks, just as in places of moderate exposure, the more abundant plants are yarrow, pearly everlasting, dune tansy, *Baccharis, Ericameria,* lupines and strawberry. The sand verbena and *Franseria* play here a rôle far less conspicuous than in exposed situations. Toward the eastern part of the area studied, where there is less wind and less of shifting sand, the brake, blackberry and poison oak occur. Still farther east one finds numerous weeds, and the characteristic plants of dry hillsides beyond the limits of the present study.

### *Undermined and Buried Vegetation*

Such shrubby plants as willow, lupines and *Baccharis* are able to withstand considerable undermining. The willow holds on as the last representative in many a moribund vegetation-capped mound. *Franseria* and tansy also are not easily killed by the blowing away of the sand from the substratum. If, however, the sand is blown away very rapidly no vegetation can survive. Here the ground will be strewn with a miscellaneous collection of roots and branches of willows, lupines and other shrubby plants.

Distributed throughout the dune area there are many small mounds 2 to 4 meters high capped with willow. These have been formed by a blowing away of the sand from all around them. When such action is not too rapid the willows may grow down the sides of the mound and thus persist for a long time. Infilling may now occur and the former mound be partly covered. Often for a time a considerable moat-like depression will encircle the mound only to be eventually filled up.

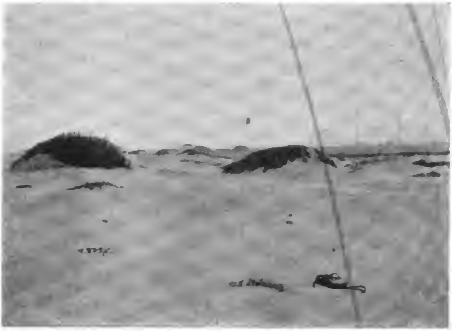

Fig. 3. Young sand verbena (*Abronia*) just getting a foothold.

The plants that best survive slow burial are the sand verbena, *Franseria,* wild cucumber and willow. If infilling is very rapid all vegetation is destroyed.

### *Associations*

Vegetation of the dunes is not readily catalogued into definite communities. One may, however, distinguish a *mixed scrub association* in the vegetation mentioned as occurring in sheltered places that are not especially moist. The lower areas, dominated by willows may be called a *willow thicket association.* These "associations," as also the pioneer groups and the relic mounds all belong to a single *sand-dune formation.*[8]

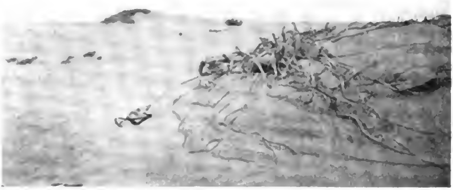

Fig. 4. A patch of *Franseria* undermined and destroyed by blowing away of the substratum.

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[8] Later stages of the mixed scrub and of the willow thicket, while not occurring in the neighborhood of the dunes, may be seen at Land's End, 3 km. to the north and beyond the Cliff House. Here there are cliffs 20 to 40 meters high, for the most part of fairly stable rock, but in places giving way to soft sandstone. Intermittent streams or storm waters have eroded this sandstone and carried down the material, forming alluvial fans. These fans differ in soil character from the dunes in that they have a certain amount of humus. Upon these fans there develops a vegetation-complex closely like that of old dunes. There are the same shrubs and herbs but in somewhat different proportions. The yellow lupine is especially prominent; *Eriophyllum* also is common. Where ravines occur in sandy soil the willow thicket becomes well developed, but here with the increased amount of humus there is a far richer flora than in the dune area. Many additional species enter the association as: *Rubus vitifolius, Vicia gigantea, Heteromeles arbutifolia, Diplacus glutinosus, Micromeria chamissonis, Sambucus glauca.*

## SYSTEMATIC LIST OF SPECIES

Following is a systematic list of dune species with various annotations. It may be well once more to remind the reader that the introduced plants do not occur on the typical dunes at all, which are still in their primaeval condition. Plants marked with an asterisk are the most characteristic dune species.

The writer is under obligation to Prof. Harvey M. Hall of the University of California for reading and correcting the manuscript of this paper and for many courtesies extended while the writer was in California.

### *Polypodiaceae*

*Pteridium aquilinum pubescens* Underw., Common Brake.
Only in well established areas near the eastern limit of dunes.

### *Poaceae*

*Chætochloa glauca* (L.) Scrib., Bristly Foxtail.
Introduced annual; low places only, with other weeds.
*Ammophila arenaria* (L.) Link., Marram Grass.
Planted as a sand binder; has become fairly well established in places close to the ocean shore; also on a few dunes where it has evidently been freely planted.
*Festuca sciuroides* Roth., Squirrel-tail Fescue.
An introduced annual; only on well-established sand.
*Bromus hordaceus* L., Soft Chess.
This introduced annual, common over wide stretches of California, is present wherever other weeds occur in well-established areas.

### *Cyperaceae*

*Eleocharis acicularis* R. Br., Slender Spike-rush.
Low, wet places among willows.

### *Juncaceae*

*Juncus lesueurii* Boland., Salt Rush.
In low places.
*Juncus phæocephalus* Engelm., Rush.
Low areas, among willows.

### *Salicaceae*

**Salix lasiolepis* Benth., Arroyo Willow.
Here it is mostly 1 to 3 meters tall.

*Polygonaceae*

*Chorizanthe pungens* Benth.
Annual; looks like a small *Eriogonum*.
*Eriogonum latifolium* Smith.
About 6 dm. tall.
*Rumex acetosella* L., Sheep Sorrel.
Introduced weed in eastern part of dune area.
*Rumex salicifolius* Weinm., Willow Dock.
In low places with established vegetation; 3 to 5 dm. tall.
*Polygonum paronychia* C. & S.
About 2 dm. tall. The specific name suggests the appearance; the plant does not look at all like a *Polygonum*.

*Nyctaginaceae*

* *Abronia latifolia* Esch., Yellow Sand Verbena.
Forming large prostrate mats, often one meter across.

*Tetragoniaceae*

*Mesembryanthemum aequilaterale* Haworth, Ice Plant.
Occasional, especially within a moderate distance (100–200 meters) from the ocean.

*Corrigiolaceae*

*Pentacaena ramosissima* H. & A., Sand Mat.
Prostrate; forming dense mats.

*Papaveraceae*

*Eschscholtzia californica* Cham., California Poppy.
This annual, which is so abundant in many parts of the state, is present occasionally on well established areas; plants are of about the usual height.

*Rosaceae*

*Rubus vitifolius* C. & S., Blackberry.
Only in well established areas; moist soil.
**Fragaria chilensis* Duch., Sand Strawberry.
Prostrate; spreading by runners.

*Fabaceae*

**Lupinus arboreus* Sims., Tree Lupine.
This shrubby yellow-flowered species reaches a height of 6 dm., in exposed places but may be 1 to 2 meters tall where sheltered from the wind.
**Lupinus chamissonis* Esch.
This blue-flowered species is mostly 6 to 8 dm. tall; sometimes a meter high when in large clumps.

*Anacardiaceae*

*Rhus diversiloba* T. & G., Poison Oak.
In well established areas toward eastern limit of dune area.

### *Rhamnaceae*

*Rhamnus californica* Esch., Coffee Berry.
This common shrub of the coast ranges is usually much dwarfed on the dunes; it reaches here about 6 dm.

### *Cucurbitaceae*

**Echinocystis fabacea* Naud., Man Root, Wild Cucumber.
Climbing on bushes or sprawling on sand. The enormous roots are often exposed by the blowing away of substratum.

### *Onagraceae*

*Epilobium minutum* Lindl.,
Annual; 1 to 3 dm. tall.
*Epilobium paniculatum* Nutt.
Annual; 3 or 4 dm. tall.
**Oenothera cheiranthifolia* Hornem., Sand Primrose.
Prostrate, spreading.

### *Hydrophyllaceae*

*Phacelia douglasii* (Benth.) Torr.
About 2 to 4 dm. tall; only in well established areas toward eastern limit of dunes.

### *Solanaceae*

*Solanum nigrum douglasii* Gray, Black Night-shade.
Prostrate annual, in moist places; rare.

### *Scrophulariaceae*

*Scrophularia californica* Cham.
In low places with fairly well established soil; 1 to 1.5 meters tall.
*Mimulus langsdorfii californicus* Jepson, Yellow Monkey Flower.
Low places among willows.
*Castilleia latifolia* H. & A., Seaside Painted Cup.
Usually 1 to 2 dm. tall.

### *Plantaginaceae*

*Plantago patagonica californica* Greene.
A diminutive silky annual occurring in patches.
*Plantago lanceolata* L.
Introduced annual, in low places.

### *Ambrosiaceae*

**Franseria chamissonis* Less.
A low wide-spreading ambrosia-like plant about 1 dm. tall and having very thick roots. Highly variable as to canescence.
*Franseria bipinnatifida* Nutt.
Similar to the preceding but not so common.

### *Carduaceae*

*Cirsium occidentale* (Nutt.) Jepson.
A white cottony plant about 4 to 6 dm. tall.
**Achillea lanulosa* Nutt., Yarrow.
Common; generally 3 to 4 dm. tall.
**Tanacetum camphoratum* Less., Dune Tansy.
Common; 4 to 6 dm. tall.
*Artemisia pycnocephala* DC., Sand Sagebrush.
Not common; about 6 dm. tall; sometimes forms large patches.
*Eriophyllum staechadifolium* Lag., Lizard Tail.
Diffuse undershrub, 6 dm. tall.
**Anaphalis margaritacea* (L.) B. & H., Pearly Everlasting.
Occurs in large clumps; plants 4 to 6 dm. tall.
**Ericameria ericoides* (Less.) Jepson.
Heath-like plant, 4 to 8 dm. tall; forming compact growth.
*Erigeron canadensis* L., Fleabane.
Introduced annual in well established soil.
**Baccharis pilularis* DC., Chaparral Broom.
On the dunes this is a low shrub 2 to 4 dm. tall.

### *Cichoriaceae*

*Agoseris apargioides* (Less.) Greene, False Dandelion.
Mostly 0.5 to 1.5 dm. tall.
*Lactuca scariola* L., Prickly Lettuce.
Introduced annual, in well established soil.

## SUMMARY

The sand dunes of San Francisco lie close to the Pacific Ocean south of Golden Gate Park, extending about 5 km. north and south and 2 to 4 km. east and west. The chief pioneer plants of the dunes are *Franseria chamissonis* and *Abronia latifolia*. Other important species are *Salix lasiolepis*, *Fragaria chilensis*, *Lupinus arboreus*, *Lupinus chamissonis*, *Echinocystis fabacea*, *Oenothera cheiranthifolia*, *Achillea lanulosa*, *Tanacetum camphoratum*, *Anaphalis margaritacea*, *Ericameria ericoides*, *Baccharis pilularis*. The vegetation is described for exposed points, protected areas, and low places; the effects of undermining and burying are briefly considered; plant associations are mentioned; there is presented a systematic list of 48 species of which 40 are native and 8 introduced. The chief part of the dunes is entirely unaffected by introduced plants.

# POROUS CLAY CONES FOR THE AUTO-IRRIGATION OF POTTED PLANTS

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The auto-irrigator[1] has been very extensively used in experimental work with plant cultures where the soil moisture content was to be maintained practically constant for long periods of time, or where the tendency of the root system to remove water from the soil was under investigation. As originally described, this instrument consists essentially of one or more cylindrical porous porcelain cups buried in the soil of the culture pot, the cup being filled with water and connected (by rubber stopper and tube) to a reservoir of water situated at a lower level. As water is removed from the soil by the plant roots, or through direct evaporation, the capillary equilibrium between the soil water and the water imbibed in the porous porcelain of the cup is disturbed, and water moves from the cup wall into the soil, the porcelain being continually replenished from the cup cavity and eventually from the reservoir. The soil moisture content when cup and soil are in moisture equilibrium may have almost any value, according to the kind of soil employed and the height of the water column connecting the cup with the reservoir. When it is inconvenient to give this column the actual height required, a U-tube is inserted in the supply tube and sufficient mercury is placed therein to give the desired pressure equivalent. Then all the water absorbed by the soil is drawn from the reservoir against a pressure equivalent to that of the water column plus that of the mercury column used as a barostat. If a sufficiently large number of cups are used, to give the requisite rate of water movement, the apparatus functions with relatively very great precision, automatically adding water to the soil about as rapidly as the plant absorbs it, and the soil moisture content fluctuates over a range of only a few per cent., on the basis of soil weight or soil volume, no matter what may be the fluctuations in the rates of transpiration, evaporation and root absorption.

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[1] Livingston, B. E., A method for controlling plant moisture. Plant World **11:** 39–40. 1908. Hawkins, Lon A., The porous clay cup for the automatic watering of plants. Plant World **13:** 220–227. 1910. Livingston, B. E., and Lon, A. Hawkins, The water relation between plant and soil. Carnegie Inst. Wash. Pub. *204:* 1–48. 1915. Holmes, F. S., Moisture equilibrium in pots of soil equipped with auto-irrigators. Johns Hopkins Univ. Circular, March, 1917, p. 208–210.

It is clear that this arrangement requires, at all times, an adequate capillary continuity between the water of the soil and that of the porous porcelain, which means that the instrument may fail to operate if the soil retreats away from the external periphery of the cup so as to break the necessary capillary connections. In short, the outer surface of the cup must make good contact with the soil about it, or water movement will be hindered. Now, as is well appreciated by all students of soils, a three-phase soil (containing both water and gas, as well as the solid particles) is practically never a static system, even with reference to the solid phase alone. Especially when there is rapid fluctuation in the soil temperature and in the evaporation and root absorption rates (which is the case under ordinary greenhouse conditions), the solid particles of the soil are being moved about more or less continually by capillary forces and by gravitation. When the soil loses water it usually shrinks, and when the lost water is replaced the resulting swelling often fails to bring the soil mass back to exactly the form that it had before. It thus comes about that this shifting of the solid particles of the soil may often break the capillary continuity originally existing between the porous cup and the soil in auto-irrigated pots, at least for a portion of the area of contact. Of course such a reduction of the surface of adequate continuity between the water of the cup and that of the soil must reduce the rate of water movement from cup to soil under any given capillary gradient, and if the reduction is sufficiently pronounced a pronounced lag in the operation of the auto-irrigator must become evident. This difficulty has been encountered in practice, where cylindrical porous cups have been used for the auto-irrigation of potted plants, and the practical problem thus brought forward required considerable attention before a workable solution was reached.

To avoid the possibility of any very general or extensive drawing-away of the soil from the porous porcelain surface, it is only necessary to enlist the force of gravitation to maintain the desired contact. This can be done by giving a horizontal or oblique position to the porous surface with which the soil is to be kept in contact. If this surface is horizontal or oblique, and below the soil to which water is to be supplied, the shifting of the soil grains is generally so controlled by gravitation that the soil tends always to slip downward, filling any considerable openings that may occur. Consequently, contact of the soil with a horizontal or oblique surface *upon which* the soil rests is usually much more perfect than it is with a vertical surface *against which* the soil lies. Only a small component of the gravitational force is effective to press the soil laterally against a vertical porous cylinder embedded in it, and the soil tends to settle downward *past* the porous cup rather than *against* it. The desired end is partially attained by placing the porous cup with its long axis horizontal or oblique, but this method introduces other difficulties. In the first place only a portion of the *upper* half of the cup's cylindrical surface is now below the soil with which it is supposed to be in contact, for the lower half of this surface is directed toward the soil below. It is clear from this that the whole cup must be free to move downward in such a case, if good contact with the soil is to be maintained both above and below, but even this fails very largely, for the soil movements in question are not generally uniform throughout the soil mass and contact may still occur at certain places while withdrawal of the soil from the cup surface may occur at others. Furthermore, it is impossible to place a cylinder in any position so that some portions of its surface are not vertical, and vertical surfaces are to be avoided.

A horizontal plane porous surface situated below the soil mass to be supplied with water operates satisfactorily, but difficulties are met with when one attempts to arrange such a surface in a potted mass of soil. In such a case the porous plate supplying the water should be the bottom of the soil container, which necessitates that the rest of the cup, which might be conical or hemispherical, with a projecting neck, must lie below the container. Also, it is difficult to arrange for a relatively large supplying surface in such a case, as compared with the soil volume, unless the soil forms a comparatively thin layer on the horizontal porous plate.

Another way of attaining the desired end to a certain degree is of course accomplished if a plane porous surface is placed in the soil so as to face obliquely upward, but this arrangement also presents difficulties that may be easily imagined, and it is not generally practicable. On the whole, it appears that the most generally satisfactory way to install an auto-irrigator is to employ a porous cup having a *conical* surface, the circular base of the cone resting on the bottom of the soil container, or being not far above it, and the axis of the cone being vertical. This arrangement furnishes an oblique porous surface along which the soil may gradually slip downward, becoming always more effectively pressed against the cup. This is particularly true when the walls of the soil container also have the form of a cone, the apex pointing downward, as in the case of an ordinary flower pot. The slightly inclined wall of the pot tends to throw the downward moving soil laterally against the conical porous cup within. This arrangement furnishes a relatively large water-supplying surface, as related to the soil volume, and the surface is so exposed as not only to provide good contact with the soil at all times but also to lie in a practically ideal position with reference to downward-growing roots, which automatically tend to approach the source of water supply as they grow.

After preliminary experimentation suitable porous porcelain cones for auto-irrigation have been made available at a reasonable price. They are somewhat like the Bellani plate used in atmometry,[2] but the sloping wall is conical instead of hemispherical and is porous instead of being glazed. The new cones resemble, in form, an ordinary funnel, if we suppose the large opening of the latter to be closed by a circular plate. The whole is made of porous porcelain, but any portion of the external surface may be water-proofed if this is needed. For general use in auto-irrigation it is perhaps best to water-proof the circular plate forming the base of the cone and to treat the cylindrical neck, through which connection is made with the supply reservoir, in the same way. The neck projects vertically above the conical part of the cup and its upper end approaches or reaches the soil surface, or may project above it. The best results are to be expected when the circular base rests directly on a rigid support, such as the bottom or the sloping walls of the soil container. The diagram of figure 1 shows the general arrangement, and is self-explanatory. If the soil container is large enough several cones should be placed side by side. For deep containers it may be desirable to place several cones one above another, but they should all be rigidly supported in some suitable way; for it is not desirable that the cone should be lowered by shrinkage of the underlying soil.

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[2] Livingston, B. E., A modification of the Bellani porous plate atmometer. Science, n. s. **41**: 872–874. 1915.

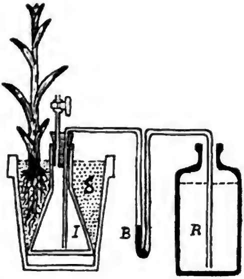

Diagram showing arrangement of auto-irrigator with porous porcelain cone *I*, cone; *S*, soil; *B*, mercury barostat; *R*, water reservoir.

The new auto-irrigator cones have a circular base 7.5 cm. ($2\frac{3}{4}$ inches) in diameter, the total height is 9.8 cm. ($3\frac{3}{8}$ inches) and the cylindrical neck is 3.7 cm. $1\frac{7}{16}$ inches) high and 2.2 cm. ($\frac{7}{8}$ inches) in diameter. The wall is about 3 mm. thick.

These cones are generally more sensitive in their responses to alterations in the moisture content of the soil around them than are vertically placed cylinders, and the improved form is desirable whenever it is requisite to maintain the soil moisture condition with as great precision as possible. The cones should be used, also, in experiments in which rather careful measurements are to be made of the rates of loss of water from irrigator to soil.

For the ordinary culture of plants, where detailed measurements of the rates of water absorption by the soil are not needed and where considerable fluctuations in the soil moisture content do not need to be specially avoided, the original cylindrical form of irrigator cup is quite satisfactory. In such cases it is well to employ as many as four or five of the regular "soil cups" furnished by the Plant World, for a single cylindrical soil container about 15 cm. in diameter and in height, In such cases, and where several of the new cones are to be operated together in the same instrument, the several units are of course to be connected together in series, by means of bent glass, hard rubber or metal tubes, so that all can be filled and emptied through the same pair of main tubes. Each cup is closed by a rubber stopper bearing two tubes, one of which does not reach inward beyond the stopper while the other reaches to the bottom of the cup (if it is desired to empty the system from time to time). The first tube of one unit is continuous with the second of the next unit in the series. At one end of the series, the shorter tube terminates above with a stop-cock or other means of opening and closing. At the other end of the series the longer tube is joined to the reservoir, either directly or through the U-tube of a mercury barostat. Suction at the open stop-cock results in filling the whole system from the reservoir, after which the cock is closed. It is well to open the cock from time to time and test the system for contained gas by suction; if there is any gas in any of the cups it will thus be removed. When the system is to be emptied, without disturbing the culture, the cock is opened and slight air pressure is applied, forcing the water out through the supply tube. A little water of course always remains in the cups after this operation, but this will soon be removed to the soil. Readings are of course obtained by measuring the amount of water removed from the reservoir which may have any convenient form.

It may be added that the new porous cones may be employed in atmometry, like Bellani plates, by water-proofing the cylindrical and conical portions of the exterior and grinding the circular base to a plane porous surface. For water-proofing this porous ware (which it is difficult to glaze in a satisfactory manner), Valentine's "Valspar" varnish, perhaps diluted a little with benzene, is found to be very satisfactory, better than alcoholic solution of gum shellac. Wherever a circular porous clay plate with a water container behind it is needed, these cones, or the Bellani plates just mentioned, may be of use.

# THE GENUS MORINDA IN THE HAWAIIAN FLORA

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The Hawaiian flora presents many interesting problems to the student of plant distribution. A very high percentage of the native vegetation is endemic—a larger percentage, in fact, than occurs in any other region of like area. The search for evidence bearing upon the origin of these endemic forms is one of the outstanding problems of the phytogeography of the Pacific region.

An excellent instance of the local peculiarities in plant distribution is the rubiaceous genus *Morinda*. This genus, (Sphaerophora Bl., Guttenbergia Zoll., Rennellia Korth., Tribrachya Korth., Imantina Hook. fil.), of shrubs, trees, and small climbers, comprises about 60 described species. A few of the species are epiphytic. The generic name is from the Latin *morus*, mulberry, and *Indica*, Indian, and several of the species are known popularly as "Indian mulberry." The East Indian name is *ach*. The genus is distributed through tropical Asia, Australasia, and the islands of the Pacific; there are a few forms in tropical America and Africa. Most of the species occur in southwestern Asia; as one travels eastward through Malaya, Australia, and the Central Pacific, the representation rapidly diminishes, and in the isolated Hawaiian Archipelago there are but two species,[1] one introduced and the other endemic. Several fossil species have been reported from the Tertiary of Europe; the total number is about seven.

The characters of the genus are briefly as follows: Leaves opposite, rarely in 3's. Stipules membranous, connate inside the petioles. Flowers sessile, in small, globose heads, which are axillary or terminal, simple, panicled, or umbellate. The flowers are white or crimson and are united at the base. The calyx is cup-shaped, truncate. The calyx-limb is short and scarcely toothed. The corolla-tube is short or long, funnel-form, salver-form, or campanulate; lobes 4 to 7; coriaceous, valvate in the bud. Stamens 4 to 7, usually 5, the filaments adnate to the throat of the corolla. Anthers enclosed in the tube or rarely exerted. Ovary 2-loculed, or by the prolongation of the placantas spuriously 4-loculed. One erect ovule in each locule. The styles are united, exerted, bifid or entire. The fruit is an aggregate of the succulent, coalescing drupes, forming a syncarpium. The pyrenæ or putamen are cartilaginous. The seeds are obovoid or reniform, with a thin testa. The albumen is fleshy. The embryo is terete, with inferior radicle.

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[1] The Yaw-Weed, *M. Roioc* L., a native of Florida and the West Indies, does not occur in Hawaii. It is a prostrate branching shrub with small crimson flowers.

*Morinda* is represented in the Hawaiian flora by two species only, *M. citrifolia* and *M. trimera*. The former is an abundant and well-known dye tree of India, Malaya, and the Pacific islands. It has been carried by the Polynesians throughout their vast migrations across the Pacific, and undoubtedly in this way reached the Hawaiian Archipelago. Numerous economic plants were thus introduced by the primitive Hawaiians, and were planted extensively in their new island home. Prominent among these may be mentioned: *Colocasia esculenta, Ipomoea batatas, Musa sapientum, Artocarpus incisa, Cocos nucifera, Dioscorea* spp., *Tacca pinnatifida, Jambosa Malaccensis, Piper methysticum, Zingiber Zerumbet, Broussonettia papyrifera,* etc.

*Morinda citrifolia* Linn. is called *Noni* by the Hawaiians; this is also its Tahitian name. It ranges from Africa and southern India to Malaya, Australia, and the islands of the Pacific. The Hawaiian group constitute the northern limit of its range in the Pacific. Its geographical distribution coincides with that of many other plants that were valued by the primitive Polynesians, and clearly marks the eastward migrations of these peoples. It is a small, glabrous tree, 20 to 30 feet high. It sometimes grows as a large shrub, branching from the ground. The bark is smooth and gray. The wood is bright yellow when first cut. It is very durable, and resists the attacks of boring insects. It weighs 30 to 40 pounds per cubic foot. The branches are obtusely 4-angled.

The leaves are 6 to 10 inches long and 4 to 6 inches broad, on petioles of ½ to ¾ inch. The blade is broadly elliptic, thick, shining, and dark-green, hence the name *citrifolia*, "like the orange leaf." The veins are conspicuously impressed; the apex is acute or obtuse. As the leaf matures it turns a rich yellow, finally passing into yellow-brown. This feature of coloration before abscission is possessed by only a few Hawaiian plants. The stipules are large, ⅓ to ½ inch long, broadly oblong or semi-lunar, and sometimes 2- 3-fid. They are connate below into a loose sheath which encloses the peduncles.

The *Noni* tree is prolific and is almost continuously in flower and fruit. All stages may be found on a single tree at any season of the year. The flower heads are on short, solitary, bractless peduncles. The latter are ½ to 1½ inches long and are usually in the axil of every other pair of leaves, or leaf-apposed.

The calyx-limb is short and truncate. The corolla is white or greenish-white; tubular or funnel-shaped; 5-lobed. The tube is about ½ inch long; pilose at the insertion of the sessile anthers below its middle. The style is shortly bifid, and as long as the tube.

The fruit is yellowish, fleshy, globose or ovoid, and about 3 inches in diameter. Fruits 4 to 5 inches in diameter are not uncommon in humid districts. The flesh is very foetid while decaying. In ancient Hawaii, Fiji, and other Pacific islands the *Noni* fruit was eaten both raw and cooked, but is scarcely palatable to the Caucasian taste. An analysis of the fruit, made by the Hawaii Agricultural Experiment Station in 1914, shows the following composition:

| | *per cent* |
|---|---|
| Edible portion | 59.930 |
| Waste | 40.070 |
| Total solids | 10.970 |
| Insoluble solids | 3.160 |
| Ash | 0.838 |
| Acids as H SO | 0.303 |
| Protein | 0.631 |
| Total sugars | 3.510 |
| Fat | 0.260 |
| Fiber | 1.052 |

The fruits contain a red dye, the roots a yellow coloring principle. The tree was formerly cultivated as a dye-plant by most Pacific and southern Asian peoples. The leaves and fruits were also used medicinally. The dye *morindian* resembles the coloring principle in madder. In the East Indies the root is called *al*, n India it is known as *ach*. There has been considerable confusion in the literature as to the status of the so-called *Morinda tinctoria* Roxb., of India. The consensus of opinion now is that *tinctoria* is merely a variety of *citrifolia*, or perhaps identical with the latter. In India the tree is raised commercially on a large scale as a dye crop. It is planted from seed or from stem cuttings. At the expiration of three and one-half years from planting the trees are felled and the roots dug. The root-bark is much richer in morindian than is the root-wood, so the smaller roots are the most valuable for dyeing. The roots are cut into short lengths and then split lengthwise into three pieces. These are ground into powder in a crude hand-mill. The cloth is dyed by being boiled with this powder; the resultant color is a dull red. The Hawaiians used the *Noni* for dyeing their *kapa* or bark cloth.

A feature of the seed of *Noni* that is of special interest is the highly specialized floating bladder, with a water-tight wall, in which the seed is suspended. By this means the seed is able to endure prolonged flotation upon the ocean currents. It should be remarked, however, that the *Noni* is very rare as a strand plant on the Hawaiian Islands, and gives no evidence of marine transportation in these islands. The writer, during nine years residence and exploration in this group, has never found germinating seeds of *Morinda citrifolia* along the Hawaiian littoral.

A variety, *bracteata* Hook., is described as having stipules more acute than the species; calyx-limb often with a lanceolate or spathulate white leafy limb, sometimes three inches long. This is not known in the Hawaiian flora.

The *Noni* occurs on the lowlands of all the islands, particularly in the vicinity of present or ancient Hawaiian settlements. Although wholly capable of resisting xerophytic conditions it reaches its best development in a humid climate. It is frequent on the arid wastelands as well as in the moist valleys, but rarely rises above an elevation of 1000 feet. It was undoubtedly much more abundant in early times, under the semi-cultivation of the primitive Hawaiians, than it is at present.

The only other species of Morinda that occurs in the Hawaiian flora is *trimera* Hillebd., known to the natives as "*Noni kuahiwi*." This is an excessively rare tree, 20 to 30 feet high, and attaining a trunk diameter of about 1 foot. The wood is yellow. The branches are pale, terete, and covered with numerous lenticels. The leaves are opposite, elliptico- or obovate-oblong, 4 to 6 by 1½ to 2¼ inches, on petioles of 1 to 1½ inches. The blade is equally acuminate at both ends; chartaceous to membranous; pubescent underneath, particularly along the veins and in their axils; almost black when dry. The stipules are ¼ inch long, acuminate, and connate into a deep sheath.

The peduncles are in the axils of old leaves, and cauline, 1½ to 2 inches long. They are pluribracteate at the base—the bracts are connate, appiculate, or subulate—and often with a pair of leaflets at the middle. The flowers are 8 to 10 in a glomerule, connate at their bases. The calyx is 1 to 1½ lines long, free from the ovary, urceolate or cupulate, truncate, and with 3 toothlets, The corolla is ⅓ inch long, coriaceous puberulous, tubular-ventricose, shortly 3-toothed, with the teeth or lobules in duplicate-valvate or cucullate. There are 3 anthers, subsessile on the lower third of the corolla, oblong and included.

The ovary is small, globose-depressed, and sunken into an annular disk at the bottom of the calyx. The style is about the length of the calyx, bifid, and with one branch shorter than the other. The drupe or berry consists of 4 distinct woody pyrenae; it is fleshy and adherent with and enclosed within the globose calyx. Each pyrena has one erect seed. The calices are connate in a syncarpium, which measures about 1 inch in diameter.

This remarkable species has been found only in the forests of Hamakua, Wai-kapu, and Maka-wao, on the island of Maui. A variety *beta* is characterized by leaves thicker than those of the species, shining, ovate-oblong, obtuse. The calyx is truncate, with 5 to 6 toothlets. The corolla is occasionally 4-toothed, with 4 anthers. There are 10 to 15 flowers in a glomerule. This variety has been collected only from the summit of Mount Puakea, in the Waianae Mountains, on the island of Oahu. *Morinda trimera* is thus seen to be strictly endemic, highly precinctive, and excessively rare. Only a very few stations are recorded for it, and these are confined to the islands of Oahu and Maui. Kauai, the oldest island of the group, and Hawaii, the youngest do not possess it. The origin of this lone endemic species is indeed a mystery. From the standpoint of the ecologic factors in the environments of these two species, the evidence perhaps points to *trimera* being a mutant of *citrifolia*. In other words, *citrifolia* having escaped from cultivation and made its way into higher levels of the rain-forest, under the potent influences of a wholly new ecologic background, may have spontaneously and suddenly gave rise to *trimera*. This hypothesis is worthy of further local investigation, and may prove applicable to other instances of endemism in the Hawaiian flora.

# BOOKS AND CURRENT LITERATURE

Soil Aeration.—In a recent paper by Noyes, Trost and Yoder[1] variations in root growth under three sets of soil aeration conditions are noted. The plants employed were Christmas pepper (*Capsicum annuum abbreviatum*), head lettuce (*Lactuca sativa*), radish (*Raphanus sativus*) and green pod bean (*Phaseolus vulgaris*). These plants were grown in Wagner pots, filled with Sioux silt loam in the case of Christmas pepper and with Wabash sandy loam in the cases of the other plants. All cultures were watered in a similar manner with distilled water. One set of cultures was treated by flowing carbon dioxide continuously in at the bottom of the pots at the approximate rate of 650 cc. per hour. Another set of cultures received the carbon dioxide treatment eight hours each day while a third set remained untreated. The roots of the untreated Christmas peppers were large and fibrous while those treated continuously with carbon dioxide were dwarfed, coarse and irregular. The treated plants formed many prominent aerial roots. The roots of the plants receiving intermittent treatment were somewhat similar to those receiving the continuous treatment. The aerial portions were less affected although at first the growth of the treated plants was somewhat retarded. The root system of the carbon dioxide treated lettuce was affected to a much less extent than that of the Christmas peppers. There was an indication, however, that the departure from normal growth increased with the increase of carbon dioxide. The untreated radishes formed straight tap roots while those treated produced large numbers of small horizontal roots from the base of the bulbs. The response of the bean roots to the carbon dioxide treatments seemed quite different from those of the other plants. These roots grew very near to the openings where the gas entered and the intermittent treatment seemed to produce the best root system.

The results brought out in this paper substantiate those of some other investigators in pointing out indirectly that the oxygen requirement in soils varies for different plants. Cannon and Free[2] observed directly the root growth of *Prosopis velutina* and *Opuntia versicolor* and found that these plants responded in a different manner to various mixtures of carbon dioxide and oxygen. Livingston and Free[3] observed marked differences in the rate of water absorption by roots of willow (*Salix nigra*) and coleus (*Coleus blumei*) when the soil atmosphere of these plants was deprived of oxygen by replacing it with nitrogen. The willow showed no signs of injury when oxygen was excluded from its roots while the coleus showed an almost complete cessation of water intake within a few hours. The root system of the coleus grown with deficient oxygen was poorly developed. *Nerium oleander* and *Heliotropium peruvianum* were also found to show injury when their root systems were deprived of oxygen.

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[1] Noyes, H. A., Trost, J. F., and Yoder, L., Root variations induced by carbon dioxide gas additions to soil. Bot. Gaz. **66**: 364–373. 1918.

[2] Cannon, W. A., and Free, E. E., The ecological significance of soil aeration. Science n. s. **45**: 178–180. 1917.

It is indicated by these various experiments that injury is due to lack of oxygen necessary in the process of respiration of the root cells. The apparent exception of normal growth in *Salix* when deprived of oxygen raises the question as to whether the respiration of the roots of that plant and other similar ones might not be anaerobic.—EARL S. JOHNSTON.

A TEXT-BOOK OF BOTANY.—Still another text-book giving elements of botany![1] There is, apparently, no common opinion, nowadays, as to what constitutes *the* elements of botany. Instead, one finds almost every teacher, called upon to give a course to persons beginning to study botany, compounding this course of certain well-known ingredients, of certain subjects "which every boy should know," and of certain other topics upon the indispensable merit of which no two other teachers agree. The product commonly includes some vestiges of the Grayian "morphology," a modicum of the Sachs-Bessey-Farlow-Campbell "type" scheme, with more or less emphasis of the idea that these "types" may give a plausible indication of the course of evolution of plants, some cytology and some bacteriology perhaps of the Strasburger and Cohn kinds, some physiology, some pathology, some plant breeding, and, especially since the summer of 1914, some economic botany. This inclusion of so many topics in one general course leads in practice to the theoretic results—confusion and dissipated interest. And what confidence and understanding have botany and botanists won, among people in general by any of the methods so far followed? Medical botany long ago won its firmly established place. Agriculture and horticulture are respected and popular: but the clamor for agriculture and horticulture in the school is raised by people who do not know that their children will get little besides elementary botany of some sort or other; and the cry is caused by botanists who do not yet see what a hungry world requires of the professed students of the only organisms ever capable of furnishing food.

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[3] Livingston, B. E., and Free, E. E., The effect of deficient soil oxygen on the roots of higher plants. Johns Hopkins Univ. Cir. n. s. no. 3. **1917**: 182–185. 1917.

[1] Allen, Charles E., and Gilbert, Edward M. Text-book of Botany. Boston, D. C. Heath and Company, 1918.

Some botanists devote their lives to seeking the means by which most plants continue, as they did before they were "investigated," to send their roots down and their stems up—but who cares? Others devote precious human life to the accumulation and description of vegetable cadavers. Others spend life and time on disease and disease. But meantime green and living organisms are carrying on, in daylight and in health, the most important chemical reaction in nature, the conversion of innutritious water and carbon-dioxide into an indispensable food. Botany is the study of food production and of food producers. Anything else is something less or something other than botany. Plant pathology is less; agriculture, horticulture, forestry are less; plant breeding is less. But they are all parts of the science to which we are devoted, emphasizing now one, now another, aspect of it which especially interests or impresses us. But what the world wants it is willing to pay for. It will pay for little that it does not want. What it always wants is food. It is willing to pay for it, for its improvement in quantity, quality, and availability. It is willing to pay for what food makes in the form of various other commodities. But for the student of esthetic or sentimental or speculative botany it may have as little need and as little pay as for the man who does nothing but study blind fishes while the world is battling for life and freedom. I do not believe that the friend who was studying blind fishes years ago is studying them now; he cannot. Nor should botanists be unmoved by the world's agony or, being moved, fail to make their science meet the need, modifying their studies in order to meet the new conditions and the new demands. Does the book before us do this?

The names of the authors guarantee that the work is well done in the sense that it is done carefully and discriminatingly, the facts are well chosen, and the statements are clear and explicit. There is no assertion that the reader has seen in the book to the same effect as the preceding discussion. Perhaps it is because the authors have been parts of a great college of agriculture and closely associated with the men who have made it great, or for other reasons; but in any case they have produced a book which, while it contains many of the "knick-knacks of science," things which are curious and therefore interesting, contain also the fundamentals and the elements of that science which is one of the foundations of civilization. If the authors were conscious of this, and intended it, the reader would have been glad to have them make a summary statement to this effect at the end of the book, thereby impressing upon the mind of the student the lesson of the whole, instead of merely stopping with the last item in the last lesson.—George J. Peirce.

# NOTES AND COMMENT

Among the topographic features peculiar to the glaciated portions of the United States are small depressions, known as plunge basins, caused by the forceful erosion of waterfalls. Dr. Loren C. Petry has recently described the vegetation of one of these basins in central New York, showing that its plants are all of northern range and many of them absent from the surrounding region (Bull. Torr. Bot. Club, May, 1918). He has further described an intensive investigation of the temperature conditions of this basin, 600 by 450 feet in size and 95 feet in depth. On a warm summer day the temperature at the rim was 94° F. and in the bottom 63.5° F., while the humidities in these places were respectively 32% and 73%. The soil moisture, wind and humidity were found to vary little throughout the bottom of the basin, but the observed differences of air and soil temperature were great enough to justify the establishment of twenty stations for the measurement of these conditions. The isotherms of soil temperature were found to correspond with the zonation of the vegetation, the isotherm of 56° F. agreeing exactly with the very similar distributional areas of the five characteristic species of the floor of the basin. The isotherms of air temperature did not coincide with the distributional limits. It is rarely that the causes underlying the distribution of plant communities are so thoroughly investigated and the rôle of a particular condition so conclusively shown.

Professor William Trelease, of the University of Illinois, has published a booklet of 394 pages entitled Winter Botany (privately published, $2.50), which is a companion volume to his Plant Materials of Decorative Gardening. Keys and descriptions are given which make it possible to determine the native and introduced woody plants of the eastern and central United States in the leafless winter condition. The ingenious keys, full descriptions and excellent illustrations should make the book a very useful one for botanists and horticulturists. Many sub-tropical, European and oriental shrubs are included, as well as some that are native to the western states, and it is unfortunate—even from the gardener's standpoint—that the geographical origin of the trees and shrubs is seldom stated.

The following list of additions and corrections is made by Mr. S. B. Parish to his paper An Enumeration of the Pteridophytes and Spermatophytes of the San Bernardino Mountains, California (The Plant World, **20,** 163, 208, 245):

Page 174, after line 42 insert:
*Festuca confinis* Vasey, Bull. Torr. Bot. Club 11: 126.
Upper Transition and Canadian zones. Coon Creek: Dry Lake.
Page 175, line 1: for *Myurus* read *Myuros.*
Page 175, line 20: for *hordaceus* read *hordeaceus.*
Page 175, after line 37 insert:
*Agropyron tenerum* Vasey, Bot. Gaz. **10**: 258.
San Bernardino Mountains, Hall, acc. Hitchcock in Jepson, Bot. Cal.
Page 209, after line 17 insert: IRIDACEAE.
Page 210, after line 8 insert:
*Salix glaucops* Anderss. in DC. Prodr. 10, pt. 2: 281.
Dollar Lake, in the Canadian zone, Hall 7867.
*Populus tremuloides* Michx. Fl. Bor. Am. 2: 243.
Fish Creek, in the Canadian zone, Grinnell.
Page 211, line 1: for *longispicatum* read *longispicum.*
Page 211, after line 37 insert:
*Eriogunum microthecum* Nutt. Jour. Acad. Phila. ser. 2, 1: 162.
On open stony slopes, Doble, upper end of Bear Valley.
*Eriogonum nudum* Dougl. var. *pauciflorum* Wats. Proc. Amer. Acad. **12**: 264.
Frequent in dry soils in the Transition zone.
Page 214, for line 27 read: *Ranunculus oxynotus* Gray, Proc. Amer. Acad. **10**: 68.
Page 215, for line 24, read *Lesquerella Palmeri* Wats. Proc. Amer. Acad. **23**: 255. Not otherwise known from California.
Page 217, after line 24 insert:
*Ribes malvaceum* Smith, in Rees' Cyclop. 30, no. 13.
On the slopes of cañons in the Upper Chaparral zone. City Creek.
*Ribes montigenum* McClatchie, Eryth. **5**: 38.
Near the summit of San Gorgonio Mountain, in the Hudsonian zone, Abrams and McGregor.
Page 219, line 22, for *cystoides* read *cytisoides.*
Page 219, after line 12 insert:
*Rosa californica* C. & S. Linnaea **2**: 35.
Frequent on damp banks in the Chaparral and Lower Transition zones.
Page 221, line 22, for Callitricaceae read Callitrichaceae.
Page 221, line 25, for Anacardaceae read Anacardiaceae.
Page 222, line 26, after *girdiana* insert Munson.
Page 223, after line 29 insert:

HYPERICACEAE

*Hypericum anagalloides* C. & S. Linnaea **3**: 127.
Frequent in the Transition zone, forming mats on damp banks.

*Hypericum formosum* H. B. K. Nov. Gen. & Sp. **5**: 196.

Frequent in the Transition zone in damp soil.

Page 248, for line 30 read: *Fraxinus oregana* Nutt. var. *glabra* Rehder, Proc. Amer. Acad. **53**: 207.

Page 248, for line 31 read: Infrequent on stream banks in the Lower Chaparral zone. Cleghorn Cañon; City Creek.

Page 250, line 14, for *Gilia Nuttallii* Gray read var. *montana* Brand. Pflanzr. IV, 250: 125.

Page 254, after line 13 insert:

*Mimulus Parishii* Greene, Bull. Cal. Acad. **1**: 108.

Big Meadows, Hall 7571.

Page 254, after line 35 insert:

*Orthocarpus pilosus* Wats. King's Expl. **5**: 231. *Castilleja pilosa* Rydb.

Sugarloaf Mountain, Upper Transition zone, Hall 7533.

Page 257, after line 15, insert:

*Chrysothamnus mohavensis* Breene, Eryth. **3**: 113.

A desert species which reaches the eastern end of Bear Valley.

Vernon Bailey.

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# The Plant World

A Journal of General Botany

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SEPTEMBER, 1918

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# ROOT HABIT AND PLANT DISTRIBUTION IN THE FAR NORTH

HOWARD E. PULLING
*The Johns Hopkins University, Baltimore, Md.*

One of the most striking characteristics of the landscapes of north-central Canada is the monotony of the sky-line. A jagged horizon of spruce tops meets the eye everywhere except in exceedingly small areas. This predominance of spruce is usually ascribed to a tolerance of low temperatures greater than that characteristic of the dominant trees of more temperate climates. In such a statement the assumption appears to be implied that the *direct* effect of temperature upon physiological processes controls the flora of the far north. It is a purpose of this paper to point out one way in which low temperatures may retard the growth or limit the size of certain species of trees in an *indirect* way. To form a suitable background for the data to be presented it is necessary to consider briefly some of the characteristics of the region.

Physiographically, northern Canada is extremely young. A bird's-eye view would show the relative proportions of water and land so nearly equal in extent that it would require nice discrimination to determine which is in the excess. The lakes are irregular with rocky shores, lagoons and often abut upon swamps or muskegs. The rivers are alternations of rapids and falls with lake-like expansions of quiet water that are often reed girt and swampy. The land surfaces are characterized by eskers, moraines, drumlins, kames, ispatinows and till among which the scoured and striated rocks of pre-cambrian date are freely and unevenly presented. A large area in the heart of central Canada is occupied by the bed of glacial Lake Agassiz which extended from the northern part of Minnesota to about 57°35′ north latitude. This great lake bed embraces the region now

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SEPTEMBER, 1918

occupied by Lake Winnipeg and surrounding country and, extending northward, includes the western part of the Churchill river to a point below Southern Indian lake. The Nelson river rising in Lake Winnipeg, emerges from the old lake bed about a degree south of Split lake and does not reenter it. In this lake bed a heavy deposit of silicious clay has rounded the rugged outlines of the pre-cambrian rock and produced a rolling country.

One feature of the topography is the occurrence of muskeg on rather high hills where precipitation accumulates in cups dammed by the ancient rock or by the deposit of compact clay barriers that are but slightly permeable to water. Another noteworthy feature is a sharp discontinuity in the depth of soil, for bare rock may alternate with deep drift and of two neighboring hills, one may be solid rock and the other of glacial origin. However, because of temperature conditions these apparently deep soils are, in reality, often very shallow from the standpoint of penetrability. Except in the more southern portions of the region they are perpetually frozen to within a relatively short distance of the surface and mechanically this frozen layer is, of course, about as effective a barrier to root growth as rock would be.

The point to be emphasized in this paper is that through the combined agencies of past history and present climatic conditions the soils of the far north are, in general, shallow. In about latitude 56°N. and longitude 97°W. for example, frozen soil was encountered in August, 1916, at depths ranging from 2 meters on bare slopes facing south to 3 cm. on flat beaches with a north exposure. Because of these mechanical barriers to root penetration large trees of deep rooted species would not be expected unless this habit became modified, for an inadequate root system, of course, precludes the possibility of an extensive top.

If one considers the characteristic form of the visible portions of trees, habits so pronounced that the dominant trees may often be determined at a distance, it should not be surprising to find that the subterranean portions—the roots—also have definite habits. These characteristic root habits are well recognized in the cases of many cultivated plants and Cannon[1] has worked them out in great detail for some desert species. It is further possible that not only do plants differ in their root habits, as they do in their top habits, but also that they differ in the rigidity with which the habit is maintained under varying external conditions. If the root habits of some trees are rigid it would not be expected that those characterized by deep roots could exist in these northern regions, wholly apart from any direct effect of low temperatures upon their physiological processes. It is further possible that trees with sufficiently flexible root habits may be found in these thin-soil regions even though they may, under more favorable circumstances, penetrate to considerable depths.

The root habits of several trees were investigated chiefly during the summer of 1916 in a strip of country lying between latitude 55°N. and 56°N. and longitude 96°W and 98°W. in the province of Manitoba. This strip covers a portion of the region of deep, uniform clay soil in the area formerly occupied by Lake Agassiz and a portion of the shallow-soil region beyond the limits of this glacial lake. For comparison, the root systems of the same species were also investigated in a deep (several hundred feet) sandy soil in the neighborhood of the Brule river near the south shore of Lake Superior in Douglas County, Wisconsin. The characteristics of these root systems, in so far as they bear upon the points at issue, are exhibited in the accompanying figures. It should be noticed that these figures are dimensioned and not drawn to scale. To present a clearer idea of the general character of the systems the very small roots of some of the trees are not indicated in every place they occur; instead each system as a whole (or such a portion in the case of an extensive system that an idea of its character may be obtained) has been drawn and a few roots only are represented in detail. Each drawing is that of a portion of the root system of a particular individual, which was obtained by dissection from the soil mass with a pocket knife. In the drawings, principal roots are shown as in a plane and roots branching at right angles to the plane of the paper are omitted except as noted in the text. Several trees, ranging in size from those a few decimeters high to mature trees, were examined in various kinds of habitats, deviations from the type shown in the figure being noted in the text.

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[1] Cannon, W. A., The root habits of desert plants. Carnegie Institution of Washington Pub. 131. 1911.

BLACK SPRUCE. (*Picea mariana* (Mill.) BSP; *P. nigra* Link; *P. brevifolia* Peck.)—This tree is the common inhabitant of the muskegs. As indicated in the figure it is very shallow rooted even when growing in deep soil. For example, on a well drained slope with a south exposure, situated on a large island at the entrance of the Nelson river into Split lake (about 56°23′N. lat. and 96°25′W. long.) the soil was not frozen above a depth of 170 cm. The first 6 cm. were moss and leaf mold; the next 25 cm. a brown clay that was flocculated and very dry except in the upper 4 or 5 cm.[2] At 150 cm. a heavy clay was encountered that was solidly frozen at 170 cm. In this soil the black spruce roots were not found below 7 cm. although willow and white spruce roots were found at a depth of 80 cm.

Four possibilities immediately present themselves in this and the cases following that deal with shallow rooted plants: (1) The roots do not penetrate the flocculated clay because it is dry. (2) They do not penetrate it because it is cold. (3) They do not penetrate it because of its low oxygen content. (4) They do not penetrate it because the shallow root-habit is inflexible. Considering these briefly it may be stated that the last is the most probable because (1) black spruce is shallow rooted in a well aerated, sandy soil which is more moist below the roots than about them (Brule river region). This also applies to (3). (2) Changes in soil temperature with depth cannot be effective for the temperature in the 6 cm. of moss and leaf mold was 37°F. and there was no observed change until within a few centimeters of the frozen soil; furthermore black spruce grows with frozen soil but 8 cm. below its roots. The temperatures about the roots in this latter situation were between 33° and 35°F. in August.

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[2] This dry, flocculated soil is of general occurrence in all the region examined and there is additional reason to believe that its presence is very widespread. Even when occurring under deep layers of sphagnum saturated with water it is usually dust dry, so that plants may be actually growing in a dry soil when the surface indications point to the existence of a bog. For a more complete description and an hypothesis of origin see Pulling, H. E., Some unusual features of a subarctic soil. Johns Hopkins Circular, pp. 188–190. March, 1917.

The particular plant figured was found in the deep, sandy soil near the Brule river in northern Wisconsin, a situation favoring deep root formation. The figure is considerably simplified for the plant forms a mat of fine, interlacing roots, the two longest being figured without horizontal branches.

Black spruce also grows on rocks so nearly bare that the trunks are only kept upright by the mutual interlacing of roots of neighboring trees. In crossing portages near the headwaters of the Kawakashkagami river n northern Ontario the author has observed that where smoldering moss fires had burned the interlacing roots of the spruces, the unscorched trunks, deprived of their only support, were falling in every direction. In Sesegenega lake in the course of the same river, the black spruce grows on rocky islands. The supporting mat of roots is so thin and dense that one may cut through it down to the rock in a semi-circle facing the lake and drag the enclosed body of small trees out on the surface of the water, where they will float for some time in an upright position.

The consideration of black spruce may be closed by noting that the shallowness of the root system of a species is not, of course, an infallible guide to the extent of its northerly distribution. The root habit is but one of the characteristics that must be taken into consideration in accounting for distribution in the north. Black spruce, for example, has a shallower root system than white spruce and grows in soils too shallow to support white spruce. Yet at the northern limit of its range black spruce is practically a shrub (Doobaunt lake (63°N. lat. 102°W. long.), Kath-Kyed lake (62°45′N. lat. 98°W. long) while white spruce is a fairly large tree.[3] Beyond the mouth of the Nelson river black spruce is replaced in the cold swamps along the shore of

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[3] Tyrrell, J. B., Report on Doobaunt, Kazan and Ferguson rivers and the north-west coast of Hudson Bay. Ann. Rep. (New Series) Geol. Survey Canada, Vol. 9, pp. 1F–219F. 1897. (J. W. Tyrrell was plant-collector on this expedition.)

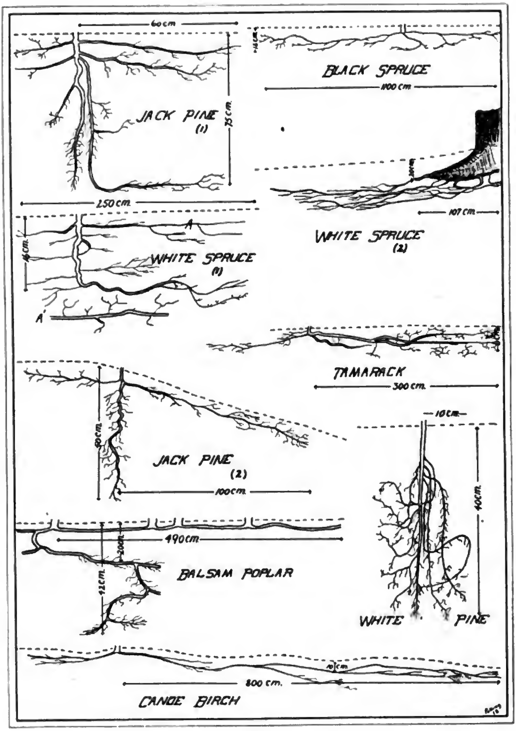
60cm
75cm
JACK PINE
(1)
250cm
A
45cm.
WHITE SPRUCE
(1)
A'
BLACK SPRUCE
1100 cm
107 cm
WHITE SPRUCE
(2)
TAMARACK
300 cm.
80cm.
JACK PINE
(2)
100cm.
10cm.
40cm.
490cm
200cm.
12cm.
BALSAM POPLAR
WHITE
PINE
10cm.
800 cm.
CANOE BIRCH

FIG. 1

Hudson Bay by white spruce, which farther south does not grow in such situations.

Jack Pine (*Pinus Banksiana* Lam.; *P. divaricata* Gordon) is a decided contrast to black spruce. It is found on drier soils, deeper soils and often appears after a fire on soil that later supports white spruce. The individual represented in figure 1, of which practically all the roots are shown, was found on the high hill overlooking the portage of the Grand Rapids of the Nelson river (about 56°10′N. lat. and 96°30′W. long.) Judging from experience, the frost line was not less than 2 meters below the surface and since in this case there was no sphagnum carpet, it was perhaps even lower. One long branch paralleled the tap root but became horizontal a few centimeters below the surface of a layer of very dense, compact clay. The tap root, however, showed no indication of becoming horizontal and, judging from other trees investigated, the tap root of this species rarely, if at all, becomes extensively horizontal. Jack pine (2), also figured practically complete, was found on the Brule river in deep sand and shows no noteworthy difference from (1) with the exception that no laterals grew parallel to the main root. Since no other tree taken in the north showed this feature it is possible that it has no significance from the present point of view.

Jack pines have been found, however, growing on rock with very scanty soil. Trees in such situations occur on the east shore of Nipigon lake in northern Ontario. But in every case examined it was found that the roots penetrated fissures in the rock and did not form a root-mat over the surface in the same way the spruces did. In consequence, the occurrence of jack pine in these situations was only occasional. The long, horizontal, surface roots, coupled with the deep tap root may indicate that the plant is able to utilize both surface and deeper water supplies.

Jack pine is apparently found as far north as deep soil is found, the limiting ice barrier in the ground being often lowered when moss fires have bared the surface to the sun's rays. It is possible that the shading produced by the growing trees themselves may increasingly hinder this summer thawing so that groves of jack pine may later be killed almost simultaneously from this cause.

J. W. Tyrrell[3] collected this species on the north shore of Selwynn lake (about 60°18'N. lat., 104°30'W. long.) only about 90 miles from the edge of the Barren Lands in that latitude, and at Theitaga lake (about 59°32'N. lat., 101°30'W. long.) which is about 70 miles from the edge of the Barren Lands, since they swing toward the south in approaching Hudson Bay.

Jack pine appears to be fairly plentiful in the rolling, deep-soil country in the bed of Lake Agassiz and rather rare eastward and northward; which may be due to the extreme shallowness of the soils outside this lake bed.

TAMARACK (*Larix Americana* Michx; *L. laricina* (DuRoi) Koch.) is, in its root habit, essentially like black spruce and like the spruce does not appear to vary the habit with changes in the depth of the soil. The tree from which the figure was taken was growing on the hill near the Grand Rapids portage on the Nelson river, in deep, thawed soil; it was about 8 years old and is almost completely figured. It grows in low regions with frozen soil a few centimeters below the surface, as does the black spruce. Similarly it is a very northern tree, J. W. Tyrrell[3] encountered frequent individuals along the Telzoa river as far as Doobaunt lake (about 63°N. lat., 102°W. long.), which is over 100 miles within the Barren Lands.

CANOE BIRCH (*Betula papyrifera* Marsh; *B. alba* L.) is apparently another shallow rooted plant. The one figured was found on the shore of Witchai lake (about 55°54'N. lat., 96°50' W. long.) in fairly deep soil with the frost line nearly two meters below the surface. This figure only shows the small terminal roots on a few of the root branches and only two of the main roots are shown, the others being similar; few in number, long and little branched. The tree was about 25 years old. Characteristically the roots are almost bare of small roots except near their tips. It is also a tree of the far north: J. W. Tyrrell[3] encountered it up to the edge of the Barren Lands. Trees large enough for canoes were found at the north end of Selwynn lake, mentioned above.

WHITE SPRUCE (*Picea Canadensis* (Mill.) BSP; *P. alba* Link.) has apparently a more flexible root habit. The plant figured as

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[4] Tyrrell, J. B., *loc. cit.*

(1) was found in the deep soil on the slope of the large island in Split lake, mentioned above. It is practically a complete figure of this seven-year-old tree. Figure A′ represents root A, viewed from above. Although the depth of this particular individual is scarcely less than that of the much older tree figured in (2) it is possible that it really does represent a difference in habit, a possibility which cannot be confirmed because of lack of information concerning the root habits of large white spruce in deep soil. In this locality, spruce roots were found about a meter below the surface and this individual was selected to show the bending of the tap root at a level determined by some cause as yet unknown.

This habit of the white spruce is decidedly different from that exhibited by it in a shallower soil. Figure 2 shows a part of a root system with the thick trunk and one of the main roots. Only a very small part of this exceedingly extensive root system is shown: the roots remain about the same in thickness for some distance beyond the limits of the figure, although much branched and many meters long. This tree was about seventy years old and was found on a large island in Split lake near the Hudson Bay Company's post. One of the noteworthy features about this system is the abruptness of the transition of thick root to thin root, even without branches. In the case of a tree 11.8 meters high, no roots were found below 35 cm. and none over 2 mm. in diameter below 26 cm. In another case a tree 14.8 meters high had only two roots over 3 cm. in diameter at a distance of 25 cm. from the tree and a depth of 14 cm. In these shallow soils it apparently forms no tap root, roots of nearly equal sizes radiating from the common center.

In the south of Canada white spruce is an inhabitant of the dryer soils, seldom being found in the muskegs with the black spruce. J. B. Tyrrell[4] records its presence as "fine, large trees" at Boyd lake on the edge of the Barren Lands (about 61°30′N. lat., 103°30′W. long.) and large trees were noted almost down to Doobaunt lake on the same river, about 100 miles within the Barren Lands. Drifted trunks of large trees were found at the junction of the Thdew river and the Telzoa river (about 64°35′N.

lat., 101°W. long.) about 240 miles within the Barren Lands. On the coast of Hudson Bay it replaces black spruce in the wet swamps. Whether these swamps are bogs is, however, uncertain.

It would seem that the root habit of white spruce should be classed as rather flexible, for it is very shallow rooted in thin soils.

Balsam Poplar (*Populus balsamifera* L.) maintains several trees on the same general root system, as indicated in the figure in which all were over twenty-five years old. These (and presumably there were others growing on the same root system) were a few meters distant from the white birch, described above. In spite of many attempts, no young trees were found, each small tree being but a branch of a larger one some distance away. The general habit of the roots is indicated in the figure, although only one is shown. These roots penetrate a short distance vertically and then send horizontal branches which sooner or later repeat the process until impenetrable soil is reached. These roots are often found very close to the frost line. It would seem, from the general appearance and the habitats that this root system is a more or less flexible one, but one that can never live in such shallow soils as the white spruce can thrive in. J. W. Tyrrell found it no farther north than the north shore of lake Athabasca (about 59°40′N. lat., 109–110°W. long.) over 150 miles south of the Barren Lands.

White Pine (*Pinus strobus* L.) is essentially a deep rooted form. Its tap root penetrates vertically with few far-reaching laterals. Another feature that seems to be noteworthy is the characteristic bunching of the roots so that but a small horizontal area is covered. It may be this characteristic that prevents its establishment in dry soils where a germinating seed is dependent upon surface water. This individual was taken in the deep, sandy soil near the Brule river. It is never found very far north of the height of land separating the lake Superior from the Hudson Bay drainage.

## GENERAL CONCLUSIONS

The foregoing discussion may be summed briefly. Root systems may be classified as deep when the habit is centered about a main, deeply penetrating tap root; shallow when this tap root is absent, and the roots remain near the surface of the soil. Various degrees of transition may be recognized but the important point, if true, is that some trees have a very rigid root habit, while with others it is more flexible. Deep root systems of an inflexible nature can not produce large trees in shallow soils, whether the shallowness is caused by rock or ice. Trees whose root systems are flexible and are not too deep rooted in deep soils may endure shallow soils. The degree of flexibility of habit and the degree of penetration in deep soils may determine the northward distribution of many plants regardless of relations between the plant and its environment that may exclude other species from those regions.

Of the species examined, Black Spruce, Tamarack and Canoe Birch may be classed as having a rigid shallow root habit; White Spruce a flexible shallow root habit; Balsam Poplar a deep, flexible root habit; Jack Pine and White Pine a deep, rigid root habit.

Other differences between the root habits that are evident from the figures are omitted from discussion as having no apparent bearing on forest composition in the far north.

# A PROMISING CHEMICAL PHOTOMETER FOR PLANT PHYSIOLOGICAL RESEARCH*

CHARLES S. RIDGWAY

*Bureau of Plant Industry, U. S. Department of Agriculture*

Botanical literature is replete with references regarding the effect of light upon plants from the viewpoint of the physiologist, the anatomist, the histologist, the ecologist and the agriculturist. Numerous methods and instruments have been devised and used, and with some success, for the determination of the intensity or nature, or both, of the insolation of the plant under observation. So far as the writer is aware, all of these methods and instruments are possessed of objectionable limitations, either in reliability, initial cost, or cost of operation. It seems advisable, therefore, to call attention to a photometer which, at the present stage in its trial, at least indicates its practicability in connection with investigations of the light relations of plants. Allusion is had to the use of oxalic acid and uranium salts as advocated by Dr. Raymond F. Bacon.[1]

Through the courtesy of the Weather Bureau of the United States Department of Agriculture and with the kind cooperation of Prof. H. H. Kimball, of that Bureau, some comparisons have been made of the records obtained by the Callender pyrheliometer with the results of exposures of the chemical photometer, with the idea of standardizing the latter.

In testing out the chemical photometer, the writer used uranium acetate and oxalic acid in the proportions of one part by weight of the former to twenty of the latter; that is, 5 cc. of a 1% (0.023 molecular) aqueous solution of the uranium salt to 20 cc. of a 5% (0.71 molecular) aqueous solution of the acid.

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* Published also in The Monthly Weather Review, March, 1918, **46**: 117-119.

[1] Bacon, R. F., A solution of oxalic acid and uranium salts as a chemical photometer. Philip. Jour. Sci. A; **5**: 281-303. 1910.

(In most of his experiments Dr. Bacon used a proportion of 1 to 10. In the present tests, however, the amount of oxalic acid was increased in order that long exposures might be made.) The solutions were brought together in Florence flasks of 100 cc. capacity, plugged with loose wads of cotton,[2] and the flasks so adjusted in holes in a blackened board that the surface of the liquid in each flask was flush with the upper surface of the board, the neck of the flask being inclined to the north so that no shadow would be cast upon the liquid. This method of excluding the light from the sides of the flask was adopted in order that only the horizontal surface of the liquid would be exposed to the sunlight and thereby be more nearly comparable with the horizontally exposed receiving portion of the pyrheliometer. After exposure the oxalic-acid-uranium-acetate mixture was titrated with potassium permanganate (2N solution) in the following manner: the mixture was increased to a convenient volume for titration, either in the original flask or after having been transferred to a beaker, by the addition of distilled water. The volume to be titrated was then heated to 70°C., made strongly acid by the addition of 1:1 sulphuric acid and the potassium permanganate end-point determined while the solution was still hot. Though Dr. Bacon states that he removed the uranium salt before titration by the addition of a slight excess of ammonium hydrate, the writer found that aliquots of the same solution gave no differences in the amount of oxalic acid present, whether the uranium was removed or not, and, therefore, did not use the ammonium hydrate. It was found that in cool weather a 10% solution of oxalic acid became supersaturated, when the temperature dropped during the night, to such an extent that the stock bottle contained crystals the following morning when it was desired to make up fresh mixtures for exposure. Because of this fact it was necessary to use double the quantity of a 5% oxalic acid solution.

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[2] The flasks could not be completely closed since Dr. Bacon says, "For all practical purposes the decomposition of oxalic acid under the influence of uranyl salts may be assumed to take place as follows: $H_2C_2O_4 \rightarrow CO + CO_2 + H_2O$." Some outlet, therefore, was necessary for the escape of the gases generated.

A series of thirteen comparisons of the chemical photometer with the pyrheliometer was run during the months of May and June, 1917. The length of exposure of the solution ranged from eight to twenty-four hours, although in most cases the flasks were first exposed after dark in the evening and taken in after dark the next evening, giving an exposure of a full twenty-four hours. The ratio of the number of calories recorded by the pyrheliometer to the number of grams of oxalic acid decomposed, for each exposure, the mean ratio of all the exposures, and the percentage departure of each from the mean were computed. It was found that, with a mean of 978 for all the exposures, in nine cases the deviation from the mean ranged between 0.2 and 3% on either side, and that of the four other exposures, one was 6% below the mean and three were 5, 7 and 8% above, respectively.

Tests to determine the stability of the oxalic-acid-uranium-salt mixture in the dark, both before and after exposure, were made repeatedly and indicated that no appreciable decomposition of the oxalic acid takes place within three days if the mixture is kept in a dark closet. The effect of the diffuse light of the laboratory was also tested. The results showed that it would be necessary to expose the photometer for several hours in order to effect a measurable decomposition of oxalic acid when the proportions mentioned above are used. The temperature coefficient of the reaction was disregarded, since Dr. Bacon states that for a remarkably wide range of temperatures this factor need not be considered.

One application of the chemical photometer was demonstrated, at least to the satisfaction of the writer, in determining with it the transmission coefficient of a piece of tobacco shade cloth of 12 by 12 mesh in connection with investigations of the light relations of the tobacco plant. A flask containing the mixture was exposed (from 9.30 a.m. to 2.30 p.m. on March 21, 1917, a cloudless, bright day) to the sunlight which passed through the cloth stretched over the South side and top of a small frame. During the same period a second flask was exposed to uninterrupted sunlight and a third to the light of a portion of the north sky together with some reflected light from a low white wall opposite the north window in which the last-mentioned exposure was made. At the end of the five hours the three flasks were titrated and the decomposition of oxalic acid (0.229 gram) in the fully insolated mixture was taken as 100%. The decomposition in the shaded flask (0.121 gram) showed that in passing through the cloth the photochemical effect of the light as measured by this reaction had been reduced to 47.2%. The decomposition in the flask exposed to the north light was 0.029 gram, or 12.6% of that which took place during the same time in the flask in direct sunlight. The figure for the transmission of the shade cloth is nearly the same as its coefficient, as determined by Professor Kimball[3] with the use of the Smithsonian silver disk pyrheliometer (42.7% at normal incidence) when it is considered that the flask under the cloth was subjected to considerable reflected light from a white wall during the exposure. The same is true of the flask exposed in a north window—that is, the percentage of total light (12.6%) also includes some reflected light from the wall to the north of the flask.

Experiments to determine the reliability of the solutions and the accuracy of titration of the oxalic acid showed, by the use of series of duplicate flasks exposed simultaneously, that there were no differences beyond an experimental error of ± 1%. The results of further experiments conducted for the purpose of measuring the intensity of the sunlight on clear days, hour by hour, produced a curve very similar to the records obtained with the pyrheliometer. This was true whether separate exposures of an hour each were made or aliquots were taken at the end of each hour from a continuously exposed volume of the oxalic-acid-uranium-acetate mixture.

From the tests outlined above, this chemical photometer seems to be affected by light in a degree comparable to the pyrheliometer in spite of the fact that the two instruments doubtless are influenced by different portions of the solar spectrum. Dr. Bacon cites several published articles tending to show that solutions of both uranium salts and oxalic acid produce absorption bands in that region of the spectrum characterized by short wave lengths, and makes the statements: " . . . . it may be considered as being fairly well established that the active rays from the sun measured by this solution are in the ultra-violet," and further, " . . . . I do not consider that there is any good reason for classifying the sun's rays into infra-red or heat rays, visible rays, and ultra-violet or chemical rays, as there are just as many chemical reactions affected by light corresponding to the visible and even infra-red parts of the spectrum as there are by the ultra-violet portion." In his Table V, however, the decomposition in a solution exposed in a quartz beaker was somewhat less than that in a similar solution exposed at the same time in a glass flask. Since the reaction does take place in a glass container, it seems probable that rays other than the ultra-violet are active upon the solution. This seems even more certain when it is considered that of the total range of ultra-violet light (3920 to 1000 Ångström units) only those over 2910 units in length reach the earth and that none less than 3000 units are capable of passing through glass. It should be stated further that the rays over 3000 units in length are not bactericidal and, hence, are probably the least active chemically of the ultra-violet portion of the spectrum so far as living organisms are concerned.[4]

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[3] See Kimball, H. H., The shading effect of wire insect cages. Monthly Weather Review, September, 1916, **44**: 501–506, for a description of his method of determining shading effect.

Granting that the chemical photometer shows the chemical effect of light belonging chiefly to the violet end of the spectrum and that the pyrheliometer records the heating effect of the entire spectrum, with its maximum in the infra-red, it seems, from the comparisons made, that the proportion of the two kinds of rays commonly obtaining in ordinary sunlight is responsible for the apparent agreement of the two methods of measurement in a majority of the tests. The cases of marked departure of the ratio of the number of calories to the number of grams from the mean of all the observations are thought to be due in most instances to the occurrence of clouds or haze which affected the intensity of the rays at one end of the spectrum to a greater extent than those at the other end. It may be stated, however, that it was thought advisable by Professor Kimball to discard some of the comparisons made because of the presence during the exposure of moving cumulus clouds which caused the recording pen of the pyrheliometer to move so rapidly that accurate evaluation of its curve was impossible. Another explanation of apparently discordant results lies in the fact that instruments of the recording pen type are liable to considerable error by lagging, especially when actuated by widely different impulses of short duration occurring in rapid succession, such as the effect of moving clouds just mentioned.

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[4] Ayers, H. S. and Johnson, W. T., The destruction of bacteria in milk by ultra-violet light. Centbl. Bakt. (etc.) Abt. **2**: Bd. 40; 1914, No. 1–8, pp. 109–131.

Until the question of the specificity of physiological effect upon plants of light rays of different wave lengths is settled to the satisfaction of plant physiologists, it seems to the writer that a means of light measurement in general by a chemical method is greatly to be desired. The spectrum of a chlorophyll solution shows definite absorption bands in the red and orange and almost general absorbtion in the blue, indigo and violet with smaller bands interspersed in other portions. The projection of the solar spectrum for some hours upon a leaf has demonstrated that photosynthesis takes place most prominently in the region of the red and to some extent at other points, though few acceptable results indicating the effect of light of various wave lengths upon other life processes of the plant have been stated.[5] As far as light is concerned, physiological investigations deal, in the main, with that factor in its totality, its effect upon plants being generally regarded as photochemical; hence, the feasibility of the chemical method of measurement herein described, should future investigations confirm its seeming usefulness.

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[5] Richter, A. (in Rev. Gen. de Bot., 1902, p. 212) indicates that the amount of photosynthesis in a leaf subjected to monochromatic light is a function of the heat energy of that light and independent of its wave length. Recent articles published in the Journal of Experimental Zoölogy by Dr. S. O. Mast deal with the stimulating effect of different spectral colors upon lower organisms. The bactericidal action of ultra-violet rays, which must be a function of wave length rather than heat, is well established, Ayers, et al., loc. cit.

Some of the probable advantages of the method are the ease and low cost with which it may be operated, the avoidance of complicated, costly and frequently unreliable mechanisms, and the reduction of error due to the personal factor in observation, so prominent in the photographic paper method. The chief values of the chemical photometer, however, if its reliability is established, will lie in the facility with which several exposures may be made simultaneously under various degrees of illumination and the fact that the solution gives an automatic integration for the time period of exposure. The automatic exposure of vessels containing light sensitive solutions by the use of clocks has been accomplished by Stone[6] and a similar arrangement may be advantageous in connection with the one just described. Though plans are made for further work with the oxalic-acid-uranium-salt photometer during the coming growing season, it is hoped that it will be carefully investigated in its application to problems in plant physiology, especially with reference to the correlation of its properties with the various life processes, since such research, though attractive, lies without the province of the writer in his present field of activity.

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[6] Stone, G. E., The relation of light to greenhouse culture. Mass. Agri. Expt. Sta. Bull. 144, July, 1913. Though the results of measurements of light by a photochemical method are stated, the details of the method are not given.

# BOOKS AND CURRENT LITERATURE

**Prothallia of Tmesipteris.**—In a Dacrydium-Podocarpus forest of Stewart Island, whose vegetation, in general appearance, "is suggestive of an age when Gymnosperms and Pteridophytes were dominant rather than Phanerogams," and in forests of Western New Zealand, Holloway[1] has discovered numerous prothalli of Tmesipteris growing in humus on fallen tree trunks and as epiphytes on the tree ferns Dicksonia and Cyathea. The tree fern Dicksonia, because of favorable external anatomy, affords a comparatively easy substratum to search, and the writer was able to find between 60 and 70 gametophytes in various stages of development. Search for the prothalli is rendered difficult on account of their subterranean location, the dense growth of Tmesipteris due to vegetative reproduction, and the germination of spores only under the most favorable conditions, and but few of these rare and important stages in the life cycle of Tmesipteris have been reported.

The prothallus is cylindrical in form, brown at first but becoming darker with age, 1 to 18 mm. in length; it is covered with numerous long, golden-yellow rhizoids, never reaches the light and is destitute of chlorophyll. The unbranched, carrot-shaped form eventually branches dichotomously or trichotomously, and one of the branches thus formed may branch again. Figures showing the unbranched prothallus resemble in outline the illustration of the gametophyte of Helminthostachys, while those of the branched forms appear like the gametophyte of Ophioglossum figured in Campbell's Mosses and Ferns. A mycorhiza is present in the central portion of the prothallus, but the fungus-infested region does not form a definite zone like that of Lycopodium gametophytes. The condition of the prothalli found indicates that the spore germinates into a filament about three cells in length which gives rise to a mass of cells probably comparable to the primary tubercle of *Lycopodium cernuum*, but instead of a filament, this mass is succeeded above by another larger swelling, and so on to the apex of the gametophyte which is bluntly rounded. Growth of the gametophyte is not checked by the production of a sporophyte.

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[1] Holloway, Rev. J. E., D.Sc. The prothallus and young plant of Tmesipteris. Trans. of the New Zealand Institute, Vol. L, 1917.

Sexual organs are distributed over the entire surface as a rule, although in a few cases, one surface was quite free from both sexual organs and rhizoids, thus suggesting dorsiventrality. Both antheridia and archegonia are found in large numbers intermingled on the same gametophyte, arising in acropetal succession from the apex. The antheridia form hemispherical protuberances when mature; the archegonia have straight projecting necks which later are cut off so that the appearance is much altered,—a condition that has been misinterpreted by Lawson.[2] Mature antheridia present an appearance similar to the marginal antheridia of Equisetum in their projecting nature; they possess a quadrangular opercular cell which disintegrates, allowing the escape of the sperms. The projecting portion of the antheridial wall originates from the primary wall cell and is one cell thick; the basal part of the wall comes from the cells bordering the spermatogenous tissue which develops from the inner or primary spermatogenous cell. Unfortunately neither sequence of cell divisions nor spermatogenesis was worked out, nor does either description or figure reveal the type of sperm. In archegonial development the primary neck cell produces a neck of three or four tiers of four cells each, which eventually is cut off. The author states that he failed to determine the sequence of divisions here also, but that a basal cell is not formed.

Fertilization is not taken up. After enlarging considerably, the fertilized egg divides equatorially into epibasal and hypobasal cells, and the hypobasal half again divides by a vertical wall. From here on the sequence is uncertain so far as the paper is concerned. An apical cell is formed from tissue developed by the epibasal cell according to the writer's interpretation, thus suggesting Equisetum and Ophioglossum, and disagreeing with Lycopodium, while the hypobasal cell gives rise to the foot. The latter consists of numerous, finger-like haustoria which penetrate the gametophytic tissue and are in close relation above with the main vascular strand of the sporophyte. Just above the foot is a meristematic zone which the writer is unable to interpret. No cotyledon appears, the first leaves coming in late in the form of scales, from segment of the apical cell. The young rhizome is a monarch protostele which passes into a siphonostele with several xylem groups, in the older rhizomes—a condition "in no wise occasioned by any branching of the stele." The mesarch condition is the highest level reached. No secondary xylem was found as described for Psilotum. The writer concludes with remarks on the relationships of Tmesipteris.

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[2] Lawson, A. A., The prothallus of Tmesipteris tannensis. Trans. Royal Soc. Edin. 51, pt. iii: 785–794, 1917.

In the opinion of the reviewer, the importance of the material investigated merits more careful work in illustrations. Inked lines are often incomplete, irregular in breadth, and are omitted altogether from the angles of marginal cells of several figures. The writer also is to be criticized for his use of "loose" terminology. The term "plant" obviously applies to the gametophyte as well as to the sporophyte, yet he uses it for the sporophyte only. It is to be regretted that complete series of sections could not have been obtained from such an abundance of material, especially in the study of the early embryo. However the paper is a very valuable one, and doubtless the writer will be able in later work to close the gaps.—J. G. Brown.

## NOTES AND COMMENT

The appearance of the first number of Botanical Abstracts should serve to stimulate interest in this publication, projected less than a year ago. Over two hundred papers are abstracted in ten of the departments into which botany has been divided for editorial purposes. The initial number is a splendid proof of the willingness and ability of American botanists to furnish material for a general reviewing organ, and it is also an eloquent testimonial of the substantial usefulness of such a journal. The members of the editorial board of Botanical Abstracts have now done their part in making it an actuality. Its continued appearance depends upon every botanist in the United States doing his part to secure support for it, through either personal or institutional subscriptions. The temper of mind among American men of science is now such that we are scarcely willing to depend on reviewing organs that are published in foreign languages on an extremely tardy schedule.

Mr. George B. Sudworth has continued his treatment of the conifers of the Rocky Mountain region in a Bulletin of the Department of Agriculture (No. 680), covering the genera *Larix*, *Tsuga*, *Pseudotsuga*, *Libocedrus*, *Thuja*, and *Taxus*. The form of description and maps of distribution are similar to previous bulletins in this series. A more popular treatment of the conifers of the northern Rocky Mountain region has been published by Dr. J. E. Kirkwood (Bull. 1917, No. 53, Bureau of Education). This is a very successful presentation of the botanical and ecological features of these trees from the educational standpoint.

Dr. Frank C. Baker has published an extended paper on The Productivity of Invertebrate Fish Food on the Bottom of Oneida Lake, New York. Although written with special reference to mollusks this paper contains much that is of interest to the general ecologist as well as to the student of aquatic and palustrine vegetation. The principal plant communities are described, and three maps of the vegetation of the lake are given.

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# THE ORIGINATION OF XEROPHYTISM

D. T. MacDOUGAL and H. A. SPOEHR
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The part played by aridity as an evolutionary factor in the derivation of land forms is well recognized by students of phylogeny, and the general changes in morphology which ensue in plants which move into areas with a lessened water supply have been described in a systematic manner by Bower,[1] while a discussion of certain features of the subject was presented by one of the authors in this Journal in 1909.[2]

It is clearly recognized that only plants showing specialized habits coupled with well defined anatomical features may continue to exist in places having pronounced desert conditions. Furthermore, the idea that aridity stands in a causal relation to the characters of desert vegetation bulks large in determining our thinking of these forms.

It is to be seen however that the matter has been dealt with hitherto as if the effect of aridity did not make an impression upon the plant, its living matter, or accessory structures directly. The combined effects of rapid evaporation and undeveloped drainage in desert regions has resulted in the accumulation of a greater proportion of salts in the soils than in well watered and freely drained soils, and the strand habitats of the sea-shore succulents are also high in salts, and this has caused attention to be directed to the possible effects of these substances in inducing the succulence of plants both on strands and in the desert. The formation of the spiny plants of the desert was also attributed to the possible osmotic action of these substances. Meanwhile the senior author has consistently looked to the direct

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[1] Bower, F. O. Origin of a land flora. 1908.

[2] MacDougal, D. T. Influence of aridity upon the evolutionary development of plants. The Plant World **12**: 217. 1909.

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effects of aridity for the induction of both succulence and xerophytism.

Thus it was said in 1914,

> A general parallel is offered by the behavior of a dish of hydrated gelatine which may be exposed to the air under high evaporative conditions. If the conditions of desiccation were of the intensity of the desert, the outer surface would soon become coagulated and the hardened surface would thus effectually check the loss of water from the layers beneath. This in the final analysis is what takes place in the body of the plant.' . . . . and the coincidences are so sweeping and universal as to suggest that a causal connection is present.[3]

This general idea however had but little weight, as it did not include any explanation of the mechanism of the implied changes. It would seem to require no argument to establish the statement that any form or condition of the plant dependent upon its water-relations would be directly connected with the imbibitional or water-holding capacity of the cells. It has long been recognized that the structure and chemical composition of a plant may be modified by its water relations during growth, but until recently available analyses did not include data upon which any explanation of the present problem might be based. This was finally found in the carbohydrate metabolism, and in the imbibitional action of the mucilages and proteins in plant cells.

If we turn to the previously available analyses of plants and examine them for the purpose of determining changes in the carbohydrate content as influenced by humidity and aritity, some facts of great interest are encountered. The representative data of Schloesing show the following features of tobacco plants grown in dry and moist atmospheres.

| | MOIST CONDITIONS | USUAL RELATIVE HUMIDITY |
|---|---|---|
| Cellulose | 5.36 | 8.67 |
| Starch | 19.30 | 1.00 |

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[3] MacDougal, D. T. The Salton Sea. Publ. Carnegie Inst. of Wash. No. 193. 1914. p. 178.

These figures show a greater amount of cellulose and a lesser amount of starch in the plants developed in the drier atmosphere.[4]

The possible significance of the transformations in question was not realized however until a long series of detailed analyses of the sugar content of the cacti was made at the desert Laboratory. Determinations were made in all stages of development of the plant, in all the seasons and of material subjected to various experimental conditions. Prominent among the various transformations is a change of polysaccharids into pentosans or mucilages, a conversion of carbohydrates of but little hydration capacity, into others which have a large coefficient of imbibition. This change, when accompanied or followed by the increase of the cells, results in succulence. Not all plants in which such transformations take place become succulents, but two species have been observed in which individuals growing under arid conditions become succulent and those elsewhere maintain their mesophytic character. One, *Castilleja latifolia*, was found to be characterized by a high acidity of the sap in the thin leaves, and a lower acidity in the succulent individuals. It is suggested that plants which have a type of respiration resulting in a large proportion of residual acids may be capable of succulency, but this is a matter which has not yet been substantiated by any facts beyond those cited.[5]

The depletion of the water supply may, under circumstances as noted above, result in the conversion of polysaccharids into pentosans which take up and hold in a mucilage large proportions of water. This of course is but one of the possibilities. Under other conditions a low water content causes the formation of the anhydrides, of which wall-substance or cellulose is an example, or more properly speaking such action is increased or accelerated, and the plant structure thus becomes hard and indurated, and such use of its carbohydrates is of course accompanied by a limited growth, particularly in branches and leaves where the effects of aridity would be greatest.

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[4] Schloesing, Th. Végétation comparée du tabac sous glocke et à l'air libre. Compt. Rend. Paris **69**: 353. 1869.

[5] MacDougal, Richards and Spoehr. The basis of succulence. Bot. Gaz. In press.

Spoehr, H. A. The pentose sugars in plant metabolism. Plant World **12**: 365. 1917.

The separate types of transformation of carbohydrates might take place in the same plant, in different cells. Thus some of the massive cacti have shoots from which the power of branching has been entirely lost and the stems are reduced to short, cylindrical, swollen or globose forms. The external layers of such plants exhibit the typical xerophytic anhydrous wall-formations while the cortical elements have been the scene of transformations of sugars resulting in succulency.

It has been suggested above that succulence based on the conversion of polysaccharids into pentosans may occur in plants with an incomplete type of respiration which is denoted by large proportions of residual acids. The probability of this suggestion rests upon a wealth of determinations of the acidity and sugar content of the cacti and of *Mesembryanthemum*. Similar full and detailed analyses of xerophytes are not yet available. An examination of the metabolism of these plants would in all probability reveal physical conditions which facilitate or lead to exaggeration or acceleration of the formation of anhydrous wall material.

The exposure of a plant to arid conditions might be expected therefore to be followed by a retarded development due to the lack of water necessary for the hydration of cell colloids in growth, by the accelerated formation of pentosans or mucilaginous material in the cells, leading to hypertrophy of the parenchymatous elements, or by the increased formation of wall material, especially in the external layers constituting the essential feature of xerophytism. One or all of these responses might be exhibited by plants under experimental conditions, and the subject is one which deserves the renewed attention of the experimentalist.[6] The results now available consist chiefly of data for anatomical comparisons.

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[6] Eberhardt, Ph. Influence de l'air sec et de l'air humide sur la forme et sur la structure des végétaux. Ann. Sci. Nat. VIII. **18**: 61–153. pl. 1. Jan. 1903.

The conclusions reached in this and in previous papers are to the effect that succulence results from the conversion of polysaccharids into pentosans or mucilages, and xerophytism from a conversion of the polysaccharids into the anhydrides or wall material, both transformations being induced by a depleted or lessened water supply in the cells.

# THE CLASSIFICATION OF SYMBIOTIC PHENOMENA

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Biotic factors have received much less attention from modern ecological workers than they deserve. One result of this is a lack of any general agreement concerning the status of certain common phenomena and concerning the meaning and scope of certain concepts or terms. One of the terms whose scope and definition varies greatly with different writers is symbiosis. This word is defined in text books in a great variety of ways ranging from a very narrow sense to the broadest possible interpretation. That this is true is evidenced by the following quotations taken somewhat at random from authors whose books are available to every one.

Campbell (2) states that "a special form of parasitism called symbiosis is exhibited by some fungi" and cites lichens and mycorhizas as examples. This is probably the narrowest sense in which the term will be found defined, since it is made subordinate to parasitism, though probably Campbell's conception of symbiosis is not different from that of numerous other authors.

Ganong (7), writing of mycorhizas, says: "And accordingly we have here one of the cases where two different organisms derive benefit from their association, a condition called symbiosis." The further discussion by Ganong shows that he interprets this definition in a very limited sense.

Curtis (4), also writing of mycorhizas, tells us that "this state where two or more plants live together is termed symbiosis." This sounds like a broad definition but the interpretation of it by Curtis limits it to such classical examples as lichens and mycorhizas.

Harshberger (8) says: "Some fungi are symbiotic, that is, they are found in intimate relation with chlorophyll-containing plants and obtain from them food of a carbonaceous character but without apparently injuring the green symbiont." Lichens and mycorhizas are cited as examples.

Atkinson (1) states that "symbiosis means a living with or living together, and is said of those organisms which live so closely in connection with each other as to be influenced for better or worse, especially from a nutrition stand-point." This obviously includes all parasitism under symbiosis.

Cowles (3) defines symbiosis thus: "When two or more diverse organisms live together in more or less intimate relationship the phenomenon is termed symbiosis. The phenomena included under symbiosis may be conveniently grouped under the subheads parasitism and commensalism."

Warming (11) does not give a concise definition but in a footnote he says: "A somewhat extended significance is here given to the term symbiosis." He then includes in his discussion of symbiosis practically all of the interrelations of plants with each other and with animals.

The above quotations are enough to show that there is considerable variation in definition and in the kinds of phenomena included under symbiosis in the writings of present-day workers. Let us now turn our attention to the earlier writers.

Obviously the surest way of getting at the meaning of the word as understood by the earlier writers is to obtain the opinion of the one who first introduced the term to botanical literature, namely DeBary. De Bary (5) defined symbiosis broadly as the living together of dissimilar organisms. ". . . . der Ercheinungen des Zusammenlebens ungleichnamiger organismen, der Symbiose, wie man kurtz and algemein sagen kann." That he regarded it a broader term than parasitism is shown by the fact that he says: "Die bekannteste and exquisiteste Erscheinung der Symbiose ist der Volständige Parasitismus . . . ." The further discussion by De Bary proves beyond a doubt that he intended to include under symbiosis all phenomena of the intimate association of dissimilar organisms. He mentions, for instance, epiphytes, Azolla and bluegreen algae, pollinating insects and flowers, etc. If, then, this represents accurately De

Bary's idea of symbiosis, how has the definition become so limited in the minds of many modern writers? Perhaps it is useless to speculate on this question but it may have come about in the following way.

The paper by De Bary, from which the above quotations were taken, was published as a separate and is not found in many libraries. Probably, therefore, many of the modern writers have never seen the original article. Several pages in this article are devoted to the relation between fungi and algae in lichens. The knowledge of this relation was new at that time and for that reason this part of the paper attracted most attention and was most emphasized by those who later had occasion to refer to the publication. Jost (12), for instance, makes the statement that De Bary first used the word symbiosis in connection with lichens. Now the relationship between fungi and algae in lichens was thought to be unique and entirely different from parasitism. It was a fine thing to talk about to students. It was only natural, therefore, that symbiosis should come to mean in the minds of many only that supposedly unique sort of relationship represented by lichens.

At present, of course, it is well known that the interrelation between lichen-fungi and algae is not essentially different from ordinary parasitism. It is merely what has been called reciprocal parasitism in which each organism is a partial parasite on the other. Therefore we would have no need at all of such a word as symbiosis if we were to limit it to the few known cases of reciprocal parasitism. It is a very handy word, however, when employed in the sense in which De Bary used it and should by all means be retained with that meaning.

There have been but few attempts to classify the phenomena that should be included under symbiosis. De Bary (5) himself mentioned various types of symbiosis but he did not elaborate upon their classification. Lundström (9), classifies symbiotic plant structures as follows:

Symbiotic structures of plants.
    Cecidia (antagonistic symbiosis).
            Zoocecidia (caused by animals).
        Phytocecidia (caused by plants).
            Mycocecidia (i.e. *Synchytrium*).
            Phycocecidia (cephalodia belong here).
    Domatia (mutualistic symbiosis).
        Zoodomatia (inhabited by animals).
        Phytodomatia (inhabited by plants).
            Mycodomatia (i.e. root tubercles).
            Phycodomatia (i.e. *Azolla*).

This classification, while it served the author's purpose fairly well, is too incomplete for our present purposes since it leaves disjunctive symbiosis out of consideration entirely and does not offer a satisfactory place even for such things as lichens, the cephalodia, of course, being merely cecidia-like structures occurring upon lichens.

Pfeffer (10) recognizes both conjunctive and disjunctive symbiosis, but he does not carry the classification further; and the same might be said of several other authors.

Gager (6) has recently classified symbiotic phenomena as follows:

1. Disjunctive or social
    A. Nutritive (ants and fungi)
    B. Nonnutritive (insects and pollen)
2. Epiphytism
3. Mutualism
4. Parasitism

While this classification is broad enough to include most symbiotic phenomena it appears faulty in certain respects. Pollinating insects and flowers as an example of non-nutritive disjunctive symbiosis does not appear well chosen since in the great majority of cases insects visit flowers for food. The use of the word mutualism should be discontinued, since, so far as known, there do not exist any cases of symbiosis in which two or more symbionts mutually help each other as formerly thought. The examples of so called mutualism are in reality cases of reciprocal parasitism in which each symbiont takes all he can get from the other symbionts. It would seem more logical, furthermore, to include epiphytism, parasitism and reciprocal parasitism under conjunctive symbiosis as coordinate with disjunctive symbiosis rather than to consider them as individually coordinate with disjunctive symbiosis.

The classification which is given below is believed to be at once simple enough in its conception and broad enough in its definition and scope to include all phenomena that should be embraced under symbiosis. Symbiosis is defined as the living together of dissimilar organisms. Any more limited definition proves unsatisfactory because of the difficulty of drawing lines of separation between kinds of phenomena among living things. Only by including all phenomena of the living together of organisms can this difficulty be avoided. Many authors who have taken symbiosis in a limited sense have never-the-less wished to include the leaf cutting ants and their mushroom gardens as an example of symbiosis. But there is really no essential difference between that phenomenon and the phenomenon of man and his vegetable garden: and it is only a short step from this to the phenomenon of a cow and the grass upon which she feeds. Again, many authors have included epiphytism under symbiosis. But if we call ordinary epiphytes symbionts why should we not call pseudoepiphytes, those land plants which happen to be growing in crotches or other places on trees where soil has collected, symbionts? And if we call these symbionts, why should we not take one more step and call the violet that grows under the tree a symbiont since it is living in intimate association with the tree?

No attempt has been made in the following classification to fit in examples of symbiosis in which only animals are concerned, but it is believed that zoologists as well as botanists will find that there is a place for every case of symbiosis that is well enough known to be classified.

Symbiosis—The living together of dissimilar organisms.

- I. Disjunctive symbiosis.
    - 1. Social—(plant communities).
    - 2. Nutritive.
        - a. Antagonistic — (Herbivorous mammals and plants; ants and fungi: ambrosia beetles and fungi; etc.
        - b. Reciprocal—(Pollinating animals and flowers).
- II. Conjunctive symbiosis.
    - 1. Social—(Lianas; epiphytes; *Azolla* and algae; etc.).
    - 2. Nutritive.
        - a. Antagonistic i.e. parasitism—(Ectotrophic mycorhizas; insect galls; plant diseases due to animals or plants; animal diseases; etc.).
        - b. Reciprocal i.e. reciprocal parasitism,—(Endotrophic mycorhizas; lichens; root tubercles; leaf tubercles of Rubiaceae; etc.).

Our ability to correctly place any given symbiotic phenomenon in this classification depends entirely upon our knowledge of the phenomenon and it is not impossible that some of the examples I have given will need to have their status changed when we understand them better. I have no doubt that some readers will not be ready to agree that I have correctly placed ectotrophic mycorhizas, for some of the very recent text books have retained the obsolete view that the mycorhizal fungi aid their hosts in absorbing mineral salts from the soil. But it is pretty generally agreed among recent workers on ectotrophic mycorhizas that they represent simply instances of parasitism of fungi on the roots of higher plants. Endotrophic mycorhizas, on the other hand, are somewhat comparable to the root-tubercles of legumes. None of the mycorhizal fungi, probably, are capable of fixing nitrogen; but their relation to the host is similar to that of tubercle bacteria, since, while the fungus is at first parasitic on the host, eventually, in the majority of cases at least, the higher plant becomes parasitic on the fungus. These, therefore, are instances of reciprocal parasitism.

Probably no one will dispute the status of lichens but some may object to speaking of lichens as symbiotic phenomena at all, since some prominent botanists have recently adopted the rather peculiar notion that lichens are simply fungi. The word lichen, however, has been used for a long time to mean the composite structure that results from the symbiosis of lichen-fungi with algae, and no very good reason has yet been given for changing its meaning. A lichen-fungus is a fungus; it is not a lichen. There is no more reason for calling a lichen a fungus than there is for calling a mycorhiza a fungus; and it is just as absurd to call a lichen-fungus a lichen as it would be to call a mushroom a mycorhiza.

## LITERATURE CITED

(1) Atkinson, G. F.: College Botany. 736 pp. New York. 1905.
(2) Campbell, D. H.: A University Text-book of Botany, 579 pp. New York. 1907.
(3) Coulter, J. M., Barnes, D. R., and Cowles, H. C.: A Text-book of Botany. Volume 2. Ecology. Chicago, 1911.
(4) Curtis. D. D.: Nature and Development of Plants. 506 pp. New York. 1914.
(5) De Bary, A.: Die Erscheinung der Symbiose. 30 pp. Strasburg. 1879.
(6) Gager, C. S.: Fundamentals of Botany, 640 pp. Philadelphia. 1916.
(7) Ganong, W. F.: A text-book of Botany for Colleges. Part 1, 397 pp. New York. 1916.
(8) Harshberger, J. W.: Mycology and Plant Pathology. 779 pp. Philadelphia. 1917.
(9) Lundström, A. N.: Pflanzenbiologische studien. 2. Die Anpassungen der Pflanzen an Thiere. Nova Acta. reg. sac. Scient. Ups.. Ser. 3. 2, 13. 1887. (Review in Just's Bot. Jahresb. 15. Part 1. P. 439.)
(10) Pfeffer, W.: Physiology of Plants. English Edition. Oxford, 1899.
(11) Warming, E.: Oecology of Plants. English Edition, Oxford, 1909.
(12) Jost, L.: Lectures on Plant Physiology. English Edition. Oxford. 1907.

# A SIMPLE NON-ABSORBING ATMOMETER MOUNTING

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Two non-absorbing atmometer mountings have been described, the object of which is to prevent the absorption of rain by porous cup atmometers. Each of these forms has two mercury valves, situated outside the reservoir bottle in Livingston's[1] original form, and within the bottle in Shive's[2] modification. Both of these mountings require two tubes leading into the cup, one just entering, the other extending to the top of the interior. Suction applied to the outer end of the latter tube tends to create a partial vacuum in the cup and water rises through the other tube, finally filling the cup. This method is unsatisfactory for filling cups with such large pores that air is drawn through the pores before water is raised to the cup from the reservoir. This often occurs even when the cup is wet, if the porous material is so open that the water menisci break before the cup becomes filled. This consideration applies in the case of the very porous black cups recently obtained.

For use with very porous atmometer cups, the writer has employed a simple modification of the Shive mounting. Its construction does not require the service of a skilled glass-blower. The essential parts are shown in the accompanying figure.

A piece of glass tubing of about 6 mm. bore and 18 cm. in length ($AA'$, fig. 1) and two other pieces ($BB'$ and $CC'$) that will fit closely into the first are selected. Each of the smaller ones is

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[1] Livingston, B. E. A rain-correcting atmometer for ecological instrumentation. Plant World **13**: 79–82. 1910.

[2] Shive, J. W., An improved non-absorbing porous cup atmometer. Plant World **18**: 7–10. 1915. Livingston, B. E., Atmometry and the porous cup atmometer. *Ibid.* **18**: 21–30, 51–74, 95–111, 143–149. 1915. *Idem*, Atmospheric influence upon evaporation and its direct measurement. Monthly Weather Rev. **43**: 126–131. 1915.

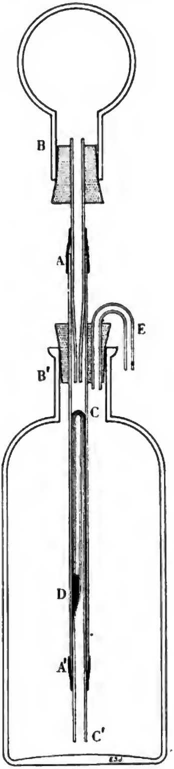

Fig. 1. Diagram showing construction of non-absorbing atmometer mounting, consisting of three glass tubes, *AA'*, *BB'* and *CC'*, and a single mercury valve *D*; *E*, air-inlet.

then drawn out into a capillary at one end. The piece *BB′* has its constricted portion from 3 to 4 cm. long, with a total length of about 10 cm. The other piece (*CC′*) has a much longer capillary portion, which is then bent back upon itself to form a J, with the shorter arm about 8 cm. in length, ending about a centimeter above the beginning of the constriction in the longer arm. The J is very narrow, so that it may slide into the tube *AA′*, as shown in the figure. The total length of the unconstricted part of this tube is such that it may reach to within about a centimeter of the bottom of the reservoir.

The tube *AA′*, after being inserted in the stopper of the reservoir, is fitted at each end with a piece of pure-gum rubber tubing 3 cm. long, in such a manner that it extends 1.5 cm. over the end. These two pieces of tubing should have a wall thickness of about 1 mm. and such a bore as to fit the smaller glass tubes rather tightly. The bent portion of tube *CC′* is then inserted into the opening *A′* of the tube *AA′*, through the rubber connection at *A′* so that the non-constricted portion extends about 2 cm. into the larger tube. Mercury is then placed in tube *AA′*, the end of the tube *CC′* being covered (at *D*) to a depth of from 6 to 7 mm. There should be enough mercury above the open end of the capillary tube to fill the latter as high as the bend. The larger end of tube *BB′* is inserted into the rubber stopper of the atmometer cup.

To install the instrument, the reservoir is filled and its stopper is inserted, carrying tubes *AA′* and *CC′* and also an air-inlet tube, *E*. Suction is next applied at *A*, so that water passes the mercury at *D* and rises to the level *A*. No air bubbles should be included. Unless the atmometer cup is too porous, it is inverted and filled with water and its stopper (bearing tube *BB′*) is pressed into place so that water rises to the end *B′*. When there is no air in tube *BB′*, the cup and tube are again inverted and the end *B′* is inserted into the water at *A* and gradually pressed through the rubber connection into the tube *AA′*, for a distance of from 5 to 6 cm. The mercury should not be forced beyond the bend at *C*.

If the cup is too porous to be mounted as just described, then its stopper is inserted and the cup is immersed in a vessel of water with the tube $BB'$ projecting upward, suction being applied at the free end. When cup and tube are filled, the end $B'$ is closed with the finger and the cup is inverted. Then the free end of the tube is opened and quickly inserted into tube $AA'$ as described above.

This instrument may be slightly modified by inserting end $A$ of tube $AA'$ in the rubber stopper of the atmometer cup and shortening tube $BB'$, so as to make the rubber connection at $A$ come to be within the cup. Such an arrangement adds rigidity, but necessitates a different method of installation. To install the instrument thus modified, insert tube $AA'$ into both stoppers. and attach rubber connections as described above. Attach a piece of thin-walled rubber tubing to end $C'$ and insert the tube $CC'$ in $AA'$. Fill both tubes by placing the end $A$ in water and applying suction at the free end of the thin-walled rubber tubing. This tubing is then closed with a tubing clamp and reversed. Mercury is dropped into end $A$ and tube $BB'$ is inserted into its place through the rubber connection, until the glass just projects beyond the latter. If this procedure does not result in completely filling $BB'$ with water additional water may be added at the open end $B$. The cup is then immersed in water and its rubber stopper is inserted under water. When tight, the mounting and cup are removed from the water and erected, the clamp on the thin-walled rubber tubing below $C'$ being released and the tubing removed just before the lower end of the mounting is inserted in the reservoir.

The mounting above described, or its modification, may be attached to any reservoir that can receive the tube $AA'$; a large-mouth bottle is not required. It is more compact than the non-absorbing forms thus far described and is less apt to suffer breakage. The rubber-tubing connections require occasional renewal, about once a month.

## BOOKS AND CURRENT LITERATURE

Civic Biology.—We believe that the appearance of this book[1] sets a new mark in biological pedagogy, for until now no work has appeared so bold as this in attack, so intensely practical, so oblivious of the aesthetic and cultural.

After five months review and personal reference to it we are frank to say that for a beginning course in biology or for work with younger pupils it is unfit because its bacteria are all pathogenic, its insects are all noxious, its mammals are all pests, its plants are nearly all weeds, and living is entirely a series of problems. Some years ago experience with a similar course led us to say, "Never again." It is too morbid for *first* impressions with pupils or students of any grade and its treatment is unfair to general biology, being highly specialized in certain phases and omitting completely certain other subjects and types. For example, the honey bee gets one page of text, ants seven; the silkworm none, mosquitoes twelve; weeds, drugs, and medicinal plants get nine pages while the apple, wheat and corn are only casually mentioned. In one short paragraph occur these terms; phagocytes, opsonins, autogenous bacterins, and opsonic index. In a later sentence are listed seventeen diseases now curable by *anti*-treatment; in the context this is statistical rather than educational. Page 348 quotes an agnostic newspaper article by an unfrocked minister, in itself remarkably good, but, we opine, entirely unfit for immature thinkers.

While it is possible that enthusiasm for the subject has led the authors to incorporate material of debatable interpretation, as Bezzola's work on alcoholic conceptions, yet they have license, for altogether too long have schools, teachers, and lay readers ignored the practical and the personal applications of scientific knowledge. *Civic Biology* will tend to counteract this. Personally we wish that the authors had done more with genetics and eugenics, for material is now available; the origin and treatment of the pauper, deficient, and criminal classes are surely civic problems. Since this is not a book for secondary schools primarily we venture to say that because some minor topics are stressed and genetics is not, herein is the weak spot.

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[1] Hodge, C. F., and Dawson, Jean. Civic Biology, pp. 381, figs. 166. Boston, Ginn and Company, 1918 ($1.60).

For a second or higher course in biology we esteem this work of Clifton Hodge and Jean Dawson of very superior merit. Not only are the specific subjects quite thoroughly treated but ample references upon them are listed and secondary topics or problems outlined for the advanced or ambitious student. Of new merit we would cite the discussion of planting home grounds, that of reforestation and the disaster of deforestation, that of bird conservation and that of fish "farming." The text is as well a laboratory guide for both teacher and worker, giving as it does directions for the solving of its problems. Its assistance in developing the "socialized" recitation and its dependence upon projects make it a source of inspiration and commends it to progressive educators.

Every teacher of biology, every physician, every minister, every worker in community welfare and social service should possess the book, and copies could well be accessible for supplementary reading in the school and public library. The diction and style render it readily understood and the colored plates and numerous illustrations are really illustrative.—HAROLD B. SHINN.

CARBOHYDRATE METABOLISM OF THE SWEET POTATO.—Recent experiments reported from the Bureau of Plant Industry[1] appear to show that free oxygen is not necessary to the formation of cane sugar. Sweet potato roots were halved lengthwise, one half being immediately analyzed and the other used in the storage experiments. Sets of these halves were subjected to air and oxygen at pressures greater than one atmosphere; to air, oxygen and hydrogen at pressure of one atmosphere; to air under a pressure of less than one atmosphere. The experiments ran from three to twenty days, and the temperature was 30°C., excepting one set of hydrogen experiments in which a temperature of 4.5°C. was used. Under pressures of 5 and 10 atmospheres potatoes were killed, and analyses revealed slight hydrolysis of starch and considerable hydrolysis of cane sugar, with increased concentration of reducing sugars. At atmospheric pressure and a temperature of 30°C. starch hydrolysis and cane sugar formation went on in hydrogen as well as in oxygen and air, the highest percentage of cane sugar occurring in the potato halves stored in hydrogen. In a hydrogen medium there was practically no increase in reducing sugars. Retardation of respiration by subjecting the potatoes to low temperature (4.5°C) and an atmosphere of hydrogen was followed by an increase in reducing sugars and later by a large increase in cane sugar, thus explaining low concentration of reducing sugars at high temperatures as due to greater respiratory activity. Potatoes stored at 30°C. for five days at less than an atmosphere (4 mm.) of air behaved like those stored in hydrogen by exhibiting increased concentration of cane sugar and but slight increase in reducing sugars. From these experiments and others carried out at the time it appears that the energy used in synthesis of cane sugar may be derived from the respiratory process, either aerobic or anaerobic.—J. G. Brown.

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[1] Hasselbring, Heinrich, Effect of Different Oxygen Pressures on the Carbohydrate Metabolism of the Sweet Potato. Journal Agricultural Research, **14**:7. August, 1918.

# NOTES AND COMMENT

The Division of Biology of the National Research Council has organized a nation-wide coöperatiion among plant physiologists and agricultural chemists, concerning the general problem of the physiological requirements of certain representative agricultural plants. This project is in charge of a special committee consisting of Professor B. E. Livingston, of Johns Hopkins University, Dr. K. F. Kellerman, of the U. S. Department of Agriculture, and Professor A. F. Woods, of the Maryland Agricultural College.

It is planned that the coöperation will carry out experimental work, by water and sand cultures, on wheat and soy bean, for a beginning. The first problem is to determine the best total concentrations and the best sets of salt proportions with 3-salt mixtures, each plant studied being considered in several phases of its development. For wheat these phases are: (1) the germination phase (until plantlets are 4 cm. high), (2) the seedling phase (for four weeks following the germination phase), (3) the vegetative phase (from end of seedling phase to appearance of flowers), and (4) the reproductive phase (from end of vegetative phase to the ripening of grain). Each phase is to be treated separately, the plants having been grown with the best 3-salt solutions for the preceding phases, respectively. Twenty-one different sets of salt proportions are to be tested with each of the six types of possible 3-salt solutions.

It is hoped that these tests may be made by a large number of experimenters in different places, all using the same methods so that the results may be comparable, and that many different climatic complexes and seasons of the year may be thus included. The general problem falls naturally into convenient portions, so that any worker or group of workers may confine attention to a certain more or less restricted field. All seeds will be supplied from the same source. Of course each worker will publish his results as he may desire, with whatever interpretation may seem warranted. It is hoped that out of this coöperation may result a clear and definite advance in our knowledge of this aspect of the physiology of nutrition, which not only may be valuable in a scientific way but also may furnish valuable suggestions to those who are experimenting with the fertilizer treatment of crop plants in the field. It is suggested that the results of this correlated set of researches may become a definite national contribution to knowledge about one of the most important and fundamental of all physiological problems. The coöperation was planned in war-time but it is as much needed in time of peace as in time of war, and it is being pushed forward with all reasonable haste.

The Special Committee on Salt Requirements of Representative Agricultural Plants has prepared a comprehensive plan for the project, which may be obtained on request, and has made arrangements for special lots of chemicals for this work, also for the special cork supports needed in water cultures. Correspondence regarding this project is earnestly requested, and all experimenters in this field are asked to join in this national undertaking in one way or another. Correspondence should be addressed to the Chairman of the Special Committee at the Laboratory of Plant Physiology of the Johns Hopkins University, Baltimore, Md.

Those who have given attention to the physical features of desert regions, on account of the features themselves or of their relation to the life of plants, animals or man, will be interested in the paper on desert erosion and degradation recently published by Prof. W. H. Hobbs (Annals of the Assn. of Amer. Geogr. vol. 7). His observations were carried out in the Libyan Desert and have to do largely with wind erosion by sand blast as a means of forming extensive depressions. There is very little desert in North America to which Prof. Hobbs' observations are directly applicable, and such attempts as he makes to shape our interpretation of American desert features by Libyan evidence are quite bootless. Even his statement that "The greater vegetation of American as opposed to Old World deserts may perhaps in part account for some difference in viewpoint" with respect to the role of large-scale erosion by sand, does not seem to clear the air for those canny ones who can tell when the cart is being put before the horse.

The Macmillan Company have published a second edition of W. S. Harwood's New Creations in Plant Life. This is a popular—in fact a somewhat cloying—account of the work of Luther Burbank, which originally appeared in 1905 and has since been reprinted six times.

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# THE QUADRAT METHOD IN TEACHING ECOLOGY[1]

J. E. WEAVER

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The quadrat method of studying vegetation has become an integral part of many of the more important ecological investigations. Although occasionally used throughout the past century for determining the amount of plant material produced or for purposes of enumeration, it was organized into a definite system for the study of the structure and development of vegetation by Pound and Clements (15, 16) and Clements (2, 3, 5) only about eighteen years ago. Since that time it has been used, sometimes in a modified form (12, 21), by numerous investigators both American and European. Indeed, with the rapid increase in the number of successional and other ecological studies the use of the quadrat and its modifications is becoming as universal as it is fundamental (6).

Not a few of the many important problems connected with grazing, land classification, indicator vegetation, afforestation, and reforestation have been solved by the aid of the quadrat method.

By the use of this method Sampson (17) has worked out a system of deferred grazing for the ranges in the national forests whereby the forage crop is utilized in such a way as to maintain the lands at their highest state of productiveness and at the same time give the greatest possible returns to the stock industry. He has also shown in a very concrete and satisfactory manner the application of a knowledge of plant succession to range management (19).

Kearney and his co-workers (10) have employed the quadrat method in the Tooele Valley of Utah, an area typically repre-

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[1] Contribution from the Department of Botany, University of Nebraska, new series, no. 23.

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sentative of many regions in the Great Basin, in answering the questions as to what types of vegetation indicate conditions of soil moisture favorable or unfavorable to dry farming and what types indicate the presence or absence of alkali salts in quantities likely to injure cultivated crops.

The studies of Shantz (20) in the Great Plains on the indicator significance of natural vegetation in determining the capabilities of land for crop production are too well known to need further comment. Indeed it is one of the pioneer investigations where ecological methods were applied to solve an economic problem.

Clements (4) made extensive use of quadrats in his study of burns and reproduction in the lodgepole forests of the Rocky Mountains. Sampson (18) has cited evidence of results accomplished in studying various forest types and makes it clear that the quadrat method has a high value in forestry and is readily applicable to widely diversified investigations in that field. Recently Hoffman (9) by employing a modification of the quadrat method has cleared up a number of important questions regarding natural reproduction from seed stored in the forest floor and has thrown new light on the whole question of natural reproduction.

In addition to these investigations, which have a direct economic bearing, numerous others should be mentioned which are important since they represent rather complete studies in different vegetational regions and are undoubtedly more accurate because of the employment of the quadrat method. Such investigations are those of Cooper (7) in the forests of Michigan, Pool (14) in the sandhills of Nebraska, Bergman and Stallard (1) in the forests and bogs of Minnesota, Gleason (8) in the prairies and forests of the inland sand deposits of Illinois, Weaver (22, 23) in the grasslands and forests of Washington and Idaho, and others.

Students of ecology, at least those somewhat advanced, should become acquainted with such investigations not only as a matter of general information, but also to learn the methods of attack and the solution of problems in ecology. But in order to appreciate such studies, a firsthand knowledge of quadrating is imperative. Unfortunately, because of the usual arrangement of the school year into semesters, field work by most students can be carried on advantageously only for a few weeks in the spring and fall. However, the accurate plotting of even one or two quadrats always teaches a great deal to the student about vegetation. Some of the more frequent lessons are: (1) the large number of species often represented in a single square meter, (2) the surprising number of individual plants growing in so small a space and the severe competition that must result, (3) something of the life histories of species, gained by seeing individuals of the same species in different stages of development, and (4) the necessity of knowing a plant, not only at the time of anthesis or at maturity, but in all stages of its development, a fact which invariably leads to closer observation on the part of the student. But in spite of these gains such a procedure frequently leaves the student with no knowledge of the greater values of such a quadrat and with the impression that vegetation is after all quite static. Could he visit these areas repeatedly from year to year and rechart these quadrats, further values would be gained. Among these would be: (1) the high mortality among certain individuals and the general difficulty of ecesis in rather stabilized areas, (2) the ephemeral nature of certain species as contrasted with the stability of others and (3) hence the variations from year to year, (4) the value of scientific accuracy in the use of the quadrat method, and especially would he profit by (5) the dynamic view of vegetation which such an investigation affords.

In order that students pursuing ecology for even a single year might derive many of the advantages of repeated yearly visits to the field the following plan of the employment of permanent quadrats of various types, in prairie, salt flats, woodland, and ruderal areas has been followed for the past three or four years. The results, from both a pedagogical and a scientific standpoint have been most gratifying and it is felt that it might be worth while presenting some of these data here. These data collected almost entirely by students have in every case been checked by a second student and the writer vouches for their general accuracy.

## ILLUSTRATIVE EXPERIMENTS IN THE SALT FLATS

A part of the territory adjacent to Lincoln and several square miles in extent is unique in that it is a salt desert, or at least is covered with halophytic vegetation (fig. 1). Although the origin of this salt basin has never been satisfactorily worked out it is believed to be due to the settling of the area to a depth of a few feet. The water of the salt lake originated from an artesian well. Much of this basin is watered by salt springs.

On a portion of these salt flats an area was selected which showed distinct zonation from the bare alkali flat to rather typical upland prairie. These zones in the order of their sequence are: (1) *Dondia depressa*, (2) *Atriplex hastata* with *A. argentea*, (3) *Distichlis spicata*, and (4) prairie. These may be seen in figure 2. Numerous soil samples were taken which proved conclusively that the zonation was not caused by differences in soil moisture. Indeed, the prairie is only about two feet higher than the bare area. A chemical analysis of the soil in the several zones was then made. Samples were taken to a depth of 8 inches soon after a rain had wet the soil to just that

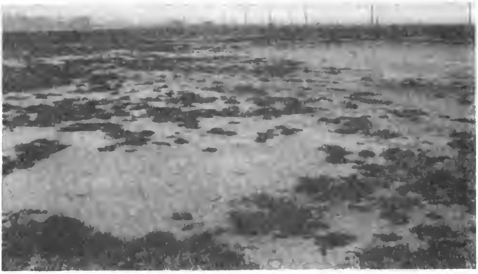

Fig. 1. A general view of a portion of the salt desert near Lincoln. The chief components of the vegetation are *Dondia depressa* and *Atriplex hastata*.

depth. This gave presumably a rather equal distribution of the salts.[2]

The distribution of the alkali in the various plant communities is shown in the table.

| | BARE AREA | DONDIA | ATRIPLEX | DISTICHLIS | PRAIRIE |
|---|---|---|---|---|---|
| Na + K | 1.502* | 1.304 | 0.878 | 0.728 | 0.418 |
| $Na_2O$ | 2.024 | 1.757 | 1.183 | 0.981 | 0.563 |
| $Na_2CO_3$ | 3.452 | 3.004 | 2.001 | 1.677 | 0.963 |

* In the table, sodium and potassium are given together. There are varying amounts of the two metals though most of the mixture consists of sodium. In the calculations only sodium has been considered and the sodium oxide and sodium carbonate have been calculated from the weight of sodium and potassium as if only sodium was present.

The table at once reveals the salt content as the controlling factor in the distribution of the vegetation. Usually *Salicornia herbacea* accompanies or even precedes *Dondia* in the saltier places but it was not present in the area under consideration. It grows in wet spots on the floor of the basin, in the saltiest of soil, often growing through a crust of salt and is frequently the sole inhabitant. (Cf. figure 3.) *Corispermum hyssopifolium* frequently occurs with *Atriplex* or covers areas exclusively where the situation is subruderal.

The area occupied by these halophytes is alluvial wash where the salt has been deposited by successive overflows year after year. Formerly it was much more extensive. The halophytes are rapidly being replaced by other species and by crop plants as the soil becomes less salty due to better drainage resulting from the straightening of stream courses. The replacement of salt grass by prairie species is often clearly marked. *Agropyrum repens* is often the first invader and is followed by *Sporobolus longifolius, Panicum virgatum, Andropogon furcatus,* and other prairie species. An interesting successional sequence was determined while making a bisect in a rich alluvial flood plain where the water level occurred in gumbo soil at a depth of about

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[2] The writer is indebted to Professor C. J. Frankforter of the department of chemistry for these determinations.

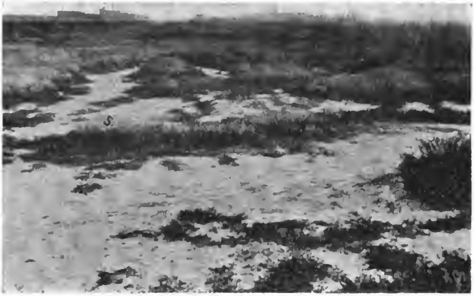

Fig. 2. A small area in the salt basin showing the zonation of *Dondia depressa* (darker border adjoining bare areas), *Atriplex hastata* (upper right portion of the figure especially), *Distichlis spicata* and prairie (just in front of and behind the man in the figure respectively). The numbers indicate the locations of permanent quadrats.

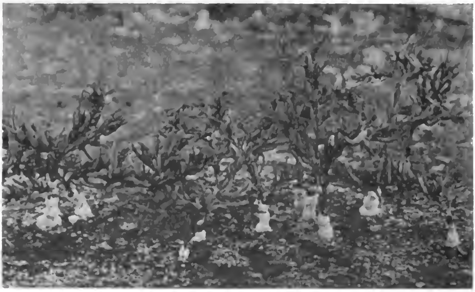

Fig. 3. Salt incrustations on *Dondia depressa*, October, 1917.

six feet. Although only an occasional specimen of *Distichlis* was to be seen, the soil contained three distinct strata of its abundant and well-preserved rhizomes at depths of 13, 9, and 6 inches respectively. These indicated successive overflows and deposits. Above these the soil was filled with a dense network of the rhizomes of *Agropyrum repens*. However, only a few of these plants were still alive, the soil being almost completely occupied by alternate areas of *Sporobolus longifolius*and *Bulbilis dactyloides*.

On the ecotones between the several plant zones in the above areas (fig. 2) several quadrats were permanently staked out, photographed and charted in the fall of 1916. Since more striking changes take place yearly among the annuals—*Dondia* and *Atriplex*—than in the more stable grass zones, a few quadrats in areas occupied largely by the former species are chosen for illustration here.

Quadrat 5 was located in such an area that it included bare alkali flat, a narrow zone of *Dondia*, and extended into the *Atriplex* area (fig. 2). Photographs of this quadrat taken in the fall of 1916, 1917, and 1918 respectively are shown in figure 4. The rank growth of *Atriplex* is due to a depression through which surface water drains after rains. The soil on either side is more salty. A study of these figures together with the chart quadrats in figure 5 reveals a number of interesting changes. One of the most striking is the almost total disappearance of *Dondia* in 1917 with the advance of *Atriplex* far out into the former *Dondia* area. A count made on June 1, 1917, showed at that time 63 and 289 Dondias respectively in the first two decimeter rows of the foreground, while the next two consisted of 966 *Dondia* and 169 *Atriplex*, rather evenly distributed. What caused this practically 100% mortality of *Dondia* in this portion of the quadrat and the dominance of *Atriplex* is a question which the student at once appreciates, and can only be solved by visits to the field during the growing season. The drought during July when only 0.56 inch of the 4.01 inches precipitation normal for that month occurred was probably the time of greatest mortality.

The thin stand of *Atriplex*, its small stature, and its presence

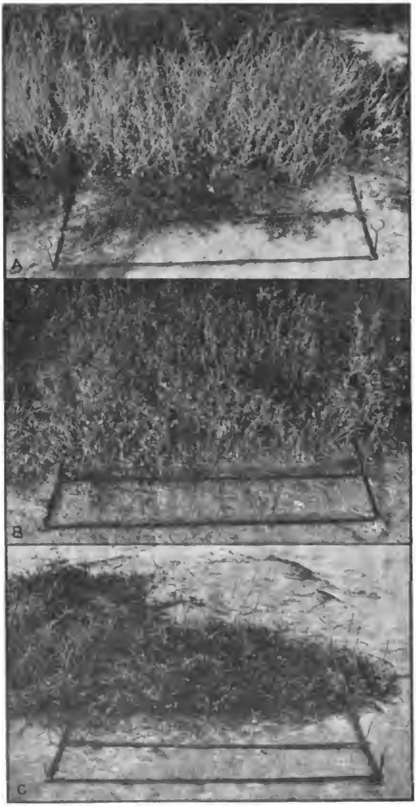

Fig. 4. Photographs of quadrat 5 in the salt flats in October, 1916 (A), 1917 (B), and 1918 (C) respectively. The chief species are *Atriplex hastata* and *Dondia depressa*.

in only the moister portion of the quadrat in 1918 is quite evident. The summer was once of severe drought. From May 1 to September 1 the precipitation was only 52% of the normal. Indeed the area yielded only 26% of its former quota of plants and these were less than half their normal size.

Quadrats 1 and 2, which were adjacent, were located in such a manner that the adjoining portions extended over a small ridge and the other ends into the *Dondia* and *Atriplex* zones.

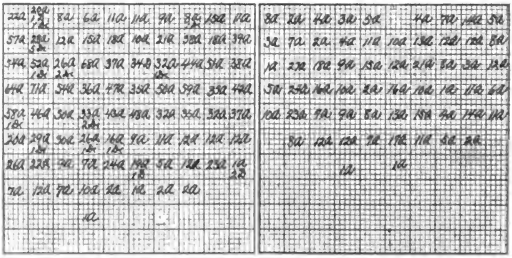

Fig. 5. Quadrat 5 charted in October, 1917 (left) and 1918. A = *Atriplex hastata*, D = *Dondia depressa*, Di = *Distichlis spicata*.

These are shown in figure 6. In 1916 the presence of *Distichlis* on the ridge indicated that it was an old eroding area. In 1917 numerous rhizomes were exposed and by 1918 living plants had entirely disappeared. The invasion of *Dondia* further into both quadrats in 1917 is quite apparent as is also the much greater abundance and extent of *Atriplex*. The small amount of *Dondia*, the reduced number of *Atriplex* and its withdrawal to the more stable portions of the area in 1918 are readily apparent. This agrees with quadrat 5 and is verified by several others.

Such an analysis by students teaches them to think in terms of vegetation and environment. The time employed in charting the quadrats is seldom over half of a day, for two students are usually assigned to only one or two quadrats. This leaves time for a general survey of the field. After the quadrating has been accurately accomplished they are furnished with the records of preceding years and are required to give a discussion at some future time of the movements of the vegetation. Not infrequently after such class discussion students voluntarily revisit the field for further data.

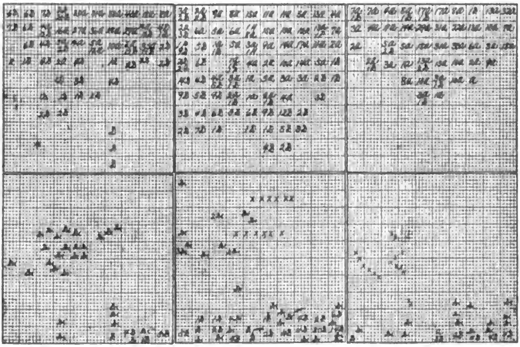

Fig. 6. Quadrats 1 and 2 plotted in October, 1916 (left), 1917, and 1918 repectively. A = *Atriplex hastata*, D = *Dondia depressa*, Di = *Distichlis spicata*, X = rhizomes of *Distichlis*, H = *Hordeum jubatum*, P = *Polygonum aviculare* R = *Rumex altissimum*.

## ILLUSTRATIVE EXPERIMENTS IN THE PRAIRIE

Rather large tracts of native grassland undisturbed except by mowing are still to be seen in eastern Nebraska. During the past few years a small area of high prairie has been set aside for investigational purposes. This is undisturbed except for denuded quadrats, planted quadrats, bisects, etc. (24). A knoll in this high prairie is underlaid with a glacial deposit of coarse gravel, a portion of which was once removed leaving a large circular depression several rods wide but only a few feet deep. The bottom of this gravel pit is rather completely revegetated. Wind erosion is wearing away the bank and uncovering the roots of the prairie plants. As the soil rolls down it forms a new area for invasion. A quadrat placed with one edge on this new area extends back into fairly stabilized vegetation, for the bank is crumbling at the rate of only 1 or 2 inches a year. Quadrats in this area have been followed since 1916. Only one need be used here. This is shown in figure 7. Beginning with the newest portion of the vegetation we find *Solidago* is a successful pioneer. It persisted, because of its rhizomes, during the dry year of 1918, while the annual *Euphorbia* and the perennial *Physalis* had entirely disappeared. *Sporobolus* and *Stipa* together with *Eragrostis* are the pioneer grasses. It is instructive to note that many of these seedlings disappear after a single year. In 1918, with few exceptions, only well-established clumps in the less densely vegetated portion of the quadrat withstood the drought. Indeed, the writer had a similar experience with a large number of prairie grasses of seven different species, the seedlings of which were transplanted from pots and watered until well established and left on June 1 in a flourishing condition.[3] All but a few of *Sporobolus* succumbed.

The more stabilized portion of the quadrat includes *Sorghastrum*, *Laciniaria*, and *Bouteloua*. Some of these are slowly increasing their area of occupation. The 1917 quadrat shows a gain of 29 per cent in the total number of individuals over that of the preceding year, but in 1918 there is even a more marked decrease. Other quadrats give similar results.

This example illustrates how a student taking ecology for only a single year may apply the most fundamental method of investigating succession, that of sequence, which consists in tracing the actual development of a community in a definite spot from year to year (Clements 1916: 423). This is the direct study of vegetation as a process. Each class passes on its results to the

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[3] These plantings were made in connection with a general study of the life histories of range plants, a field of ecology very much in need of investigation.

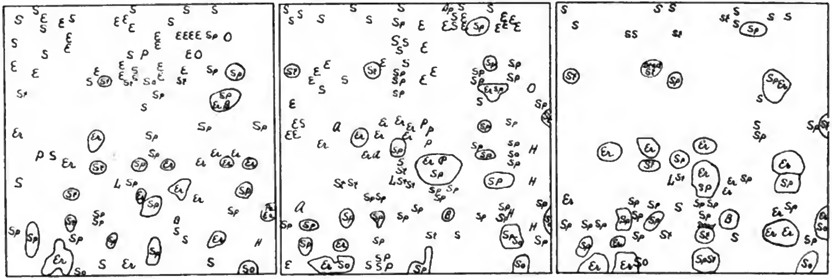

Fig. 7. A quadrat in an unstabilized area in the prairie, charted in October, 1916 (left), 1917, and 1918, respectively. The legend is as follows:

S = *Solidago missouriensis*
E = *Euphorbia serpens*
O = *Onagra biennis*
Sp = *Sporobolus longifolius*
P = *Physalis heterophylla*

St = *Stipa spartea*
So = *Sorghastrum avenaceum*
Er = *Eragrostis pectinacea*
Pa = *Panicum capillare*

L = *Laciniaria punctata*
B = *Bouteloua oligostachya*
H = *Helianthus subrhomboideus*
A = *Ambrosia artemisiaefolia*

next. These data teach greater lessons each year. The fact that all the work has been done by former students adds interest. Such a study makes the method of inference, that is the piecing together the course of development of the associes and consocies found in the region, much clearer and more accurate. Of course such work is further supplemented by permanent quadrats in stabilized areas, denuded quadrats, planted quadrats, ecotone transects extending from shrub to prairie or woodland to shrub, or across the zones of *Spartina*, *Typha*, etc., in ravines, and by bisects. A series of denuded quadrats, each set a year older than the preceding, gives at once the stages leading to stabilization. By means of these permanent studies, coupled of course with factor data and measurements of the plant responses such as transpiration, photosynthesis, and growth in the several habitats, a student is enabled to gain a maximum of results with a minimum expenditure of time.

## ILLUSTRATIVE EXPERIMENTS IN RUDERAL VEGETATION

An easy approach to the use of the quadrat method by students whose floristic knowledge is rather limited is by the study of families of large ruderals such as *Ambrosia trifida, Helianthus annuus, Iva xanthiifolia*, etc. Such work may be used to illustrate certain laws of competition in a very satisfactory manner. Necessarily competition is greatest between individuals or species which make similar or identical demands upon the same supply at the same time.

On April 27, 1916, the plants in three square meters, selected as representative of a waste area, were carefully counted. Then the quadrats were permanently marked. This area consisted of a small level tract of very rich loam soil of alluvial origin. The average number of plants per square meter was 10,500. Practically all were *Ambrosia trifida;* only a few *Polygonum pennsylvanicum* and an occasional *Solanum rostratum* were also present. At this time the plants averaged 9 cm. in height and had roots about 25 cm. long. A count on June 22 gave an average of only 206 plants per square meter, while on July 24 this number had been reduced to 100 per unit area, all of which were ragweeds. Of these 30 per cent were dominants with an average height of 2.64 m. while 70 per cent were suppressed and averaged only 1.23 m. in height. The dominants had a diameter of 1.5 cm., the suppressed group were only 0.6 cm. in average diameter.

In October another quadrat where more plants had matured was included and the number, height and diameter of the individuals were recorded. These data are shown in the table.

| NUMBER OF PLANTS | AVERAGE HEIGHT | AVERAGE DIAMETER |
|---|---|---|
| | m. | cm. |
| 192 | 2.35 | 0.7 |
| 146 | (2.27) | 0.9 |
| 88 | 2.50 | (1.2) |
| 66 | 2.66 | 1.00 |

Assuming that the quadrat with the 192 survivors had as many plants originally as the average of the other three, *i.e.*, 10,500, then the average mortality in the four areas was 98.8%, that is only 1.2% of the plants reached maturity!

This is certainly a striking lesson in competition. An examination of the table reveals a close relation between the number of individuals and their height and diameter, the plants always being larger (with the exceptions shown in parentheses) where the individuals are fewer. Competition is essentially a decrease of the amount of light, water or solutes available for each individual. By affecting these factors it affects the response of the plant. That water was an important factor was shown by the plants growing in a shallow drainage ditch. They were just as high as those on the adjacent area. Viewed from the tops of the plants one would not suspect a depression was present. On the other hand light was shown to play an important rôle for in quadrats containing an average of 16,000 individuals of *Polygonum aviculare* seedlings on April 27, 2,700 or an average of 17% reached maturity in October. Among these grass-like plants competition for light does not occur in any such degree as with the broadleaved *Ambrosia*.

This experiment was repeated by the class of 1916–17 with similar results. The mortality among *Ambrosia* averaged 95%.

The relation between number and size of plants is shown in the table.

| NUMBER OF PLANTS | AVERAGE HEIGHT | AVERAGE DIAMETER |
|---|---|---|
| | m. | cm. |
| 58 | 1.58 | 0.67 |
| 40 | 1.89 | 0.70 |
| 33 | 2.11 | 1.01 |
| 30 | (1.97) | (0.95) |

These results are very similar to those preceding.

In the spring of 1918 the struggle among 7,350, 7,100, and 10,350 individuals per square meter respectively was terminated by the area being converted into a garden. However, in the fall an examination was made to see if the same principle applied as regards competition and reduced size to a family of *Iva xanthiifolia*. The results are shown in the following table.

| NUMBER OF PLANTS | AVERAGE HEIGHT | AVERAGE DIAMETER |
|---|---|---|
| | m. | mm. |
| 79 | 1.67 | 5.9 |
| 59 | 1.72 | 7.0 |
| 45 | 1.81 | 7.2 |
| 32 | 2.11 | 9.8 |
| 29 | (2.06) | 12.7 |
| 25 | 2.37 | 13.4 |

Investigations in other areas will undoubtedly reveal similar relations.

Such studies, so elementary that a class can secure sufficient data for conclusions in a single afternoon, point the way to an investigation and discussion of some of the most fundamental questions of ecology. It involves the problems of aggregation, seed production, size and germinability of seeds, analysis of competition, causes of dominance, reactions, etc. Moreover it throws much light upon many problems in crop ecology (cf. 11). Among these are method and the rate of seeding, *i.e.*, thick or thin stand, uneven germination, and its effect upon yield, competition, effects of weeds upon cultivated crops and upon summer fallow, and many others. Of course the repeated use of the quadrat method soon reveals its bearing upon problems of grazing, crop estimation, disease survey, and forestry. It furnishes the student with a concrete basis for interpreting work already accomplished along these various economic lines.

In conclusion it may be said that it is the experience of the writer that the use of the quadrat by students teaches accuracy, inculcates habits of close observation and logical reasoning in the field. Too often students in the field are inclined to form superficial generalizations if indeed they are not too puzzled by the complexity of the problems in the general panorama, rather than to lay hold upon this problem or that phenomenon and having reduced it to order gain some definite insight into the behavior of plants in nature.

## LITERATURE CITED

1 Bergman, H. F. and Stallard, H. The development of climax formations in northern Minnesota. Minn. Bot. Studies, vol. 4, part 4, pp. 333–378. 1916.

2 Clements, F. E. The development and structure of vegetation. Bot. Surv. Nebr., no. 7, pp. 1–175. 1904.

3 Clements, F. E. Research methods in ecology, pp. 161–183. 1905.

4 Clements, F. E. The life history of lodgepole burn forests. For. Serv. Bull. 79. 1910.

5 Clements, F. E. Plant Physiology and Ecology, pp. 202–214. 1907.

6 Clements, F. E. Plant Succession, pp. 423–437. 1916.

7 Cooper, W. S. The climax forest of Isle Royale, Lake Superior, and its development. Bot. Gaz., **55**: 1–44, 115–140, Jan., Feb., 1913.

8 Gleason, H. A. The vegetation of the inland sand deposits of Illinois. Bull. Ill. St. Lab. Nat. Hist., vol. 9, art. 3, pp. 23–174, Oct., 1910.

9 Hoffman, J. V. Natural reproduction from seed stored in the forest floor. Journ Agr. Res., **11**: 1–26, Oct. 1, 1917.

10 Kearney, T. H. L. J. Briggs, H. L. Shantz, J. W. McLane, and R. L. Piemeisel: Indicator significance of vegetation in Tooele Valley, Utah. Journ. Agr. Res., **1**: 365–417, Feb., 1914.

11 Kiesselbach, T. A. Studies concerning the elimination of experimental error in comparative crop tests. Agr. Exp. St. Nebr., research bulletin, no. 13, pp. 1–95, June, 1918.

12 Oliver, F. W., and Tansley, A. G. Methods of surveying vegetation on a large scale. New Phyt., **3**: 228–237, Dec., 1904.

13 Priestley, J. H. The quadrat as a method for the field excursion. Jour. Ecol. **1**: 89, 1913.

14 Pool, R. J. A study of the vegetation of the sandhills of Nebraska. Minn. Bot. Studies, **4**: 189–312, Mar., 1914.

15 Pound, R., and Clements, F. E. A method of determining the abundance of secondary species. Minn. Bot. Studies, **2**: 19–24, June, 1898.

16 Pound, R., and Clements, F. E. Phytogeography of Nebraska, second edition, pp. 61–63. 1900.

17 Sampson, A. W. Natural revegetation of range lands based upon growth requirements and life history of the vegetation. Jour. Agr. Research, **3**: 93–148, Nov. 16, 1914.

18 Sampson, A. W. The quadrat method as applied to investigations in forestry. Forest Club Annual, Univ. Nebr., vol. 6, pp. 11–31, 1915.

19 Sampson, A. W. The application of plant succession to range management. (In press.)

20 Shantz, H. L. Natural vegetation as an indicator of the capabilities of land for crop production in the Great Plains Area. Bur. Pl. Ind. Bull. 201. 1911.

21 Tansley, A. G. Types of British vegetation. 1911.

22 Weaver, J. E. Evaporation and plant succession in southeastern Washington and adjacent Idaho. Plant World, **17**: 273–294. Oct., 1914.

23 Weaver, J. E. A study of the vegetation of southeastern Washington and adjacent Idaho. Univ. Nebr. Studies, **17**: 1–114. 1917.

24 Weaver, J. E., and Thiel, A. F. Ecological studies in the tension zone between prairie and woodland. Bot. Sur. Nebr., new series, no. 1, pp. 1–60, April, 1917.

# GEOLOGIC HISTORY OF THE LOCUST AND ITS ALLIES

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A consideration of the locust[1] and its allies introduces us to one of the largest alliances of flowering plants, popularly known as the Leguminosæ, and now divided by botanists into four families. These are the acacia or mimosa family (Mimosaceæ), the senna family (Caesalpiniaceæ), the krameria family (Krameriaceæ), and the pea or bean family (Papilionaceæ). Among these there is a well marked floral progression from the first, with its regular flowers, to the last, with its butterfly-like blossoms. The first two families are very old geologically and are largely arborescent forms of the tropical zone, many species of which have been found fossil in the Tertiary deposits of our southern states. The last two families, on the other hand, are mainly herbaceous forms dwelling outside the tropics, and both have probably attained their maximum of variation in the Temperate Zone since the inauguration of the Pleistocene glaciation.

A large number of leguminous plants furnish most important food or forage crops (Pea, bean, lentil, peanut, tamarind, alfalfa, clover, etc.) or are utilized in medicine (senna, licorice, etc.) or other arts (indigo, logwood, gum tragacanth, gum arabic, copaiba gum, etc.). The habit of many of the Leguminosæ of abstracting nitrogen from the air by means of root bacteria makes them of especial interest in these days of the rapid exhaustion of natural nitrates. Many tropical Leguminosæ are important timber trees (brazil wood, iron wood, violet wood, etc.) but outside of local uses the world's markets know but a few and these are found in the cabinet maker's rather than in the lumber trade, and scarcely any awaken a concept in the popular mind unless it be rosewood (*Dalbergia*), a tree of the pea family which furnishes such an incomparably handsome cabinet wood.

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[1] This is not the locust tree of southern Europe, which is the carob, *Ceratonia siliqua*, a member of the Caesalpiniaceae.

There are about 500 genera and 10,000 existing species of Leguminosæ, of which only 17 genera with about 32 species attain to the stature of trees within the limits of the United States, and the bulk of these are confined either to the subtropical coastal belt of Florida or to the arid southwest. The only tree forms that are widely familiar in the eastern states are the Judas-tree or Red bud (*Cercis*), the Kentucky coffee tree (*Gymnocladus*), and the honey locust (*Gleditsia*) of the family Caesalpiniaceæ and the locust (*Robinia*) of the family Papilionaceæ, so that our attention in the present article will be confined to these four trees.

### THE LOCUST (*Robinia*)

The black locust, often called the yellow locust because of its yellowish brown heart wood and yellowish white sapwood, is the type of the genus *Robinia*, so named by Linnaeus in honor of Jean and Vespasian Robin who introduced it into Europe at the end of the sixteenth century, at which time the former was in charge of the Garden of the Louvre. The specific name which Linnaeus gave this species, *pseudacacia*, commemorates in latinized form the common European name of false acacia by which this North American tree has usually been known abroad.

Its natural range extends from Pennsylvania to Georgia and westward to Iowa but it has been extensively naturalized on our western prairies as well as on the plains of Hungary. Perhaps no American tree was so extensively planted in Europe, and our colonists also, in the period immediately following the Revolution, valued it highly both for its timber and for its beneficial effect upon soils. In Revolutionary France May 6 was consecrated to the locust.

It is a medium sized tree and, while it sometimes reaches a height of 90 feet and a trunk diameter of 4 feet, the average tree branches early and tops irregularly and is not over 50 or 60 feet tall and about 20 inches in trunk diameter. The leaves, in common with nearly all the other members of the leguminous alliance, are what are known as compound, that is they consist of many separate leaflets. There are, in the locust, from 7 to 9 opposite pairs of elliptical slightly stalked leaflets and an odd one at the end terminates the slender stalk of the leaf, which is from 8 to 14 inches in length. At the base of the leaf-stalk a pair of short subulate stipules or accessory leaflets soon become transformed into straight or slightly recurved spines which persist for many years, often becoming an inch or more in length.

The flower clusters, which appear after the leaves toward the end of May, convert the tree into a creamy white bower of incense, since they are filled with fragrant nectar. The fruit, which ripens late in the autumn, is a red-brown pod, 3 or 4 inches long and ½ an inch wide with 4 to 8 smooth brown seeds, which are shed from the opened pods during the winter or early spring before the pods let go their hold on the parent tree. The locust is one of our most prolific trees in sending out sprouts from the roots, hence a tree will spread rapidly and is difficult to eradicate. It grows rapidly when young and thrives in the fertile soils of the Appalachian mountain valleys, but will also make a good growth on sandy or rocky soils.

The wood is heavy, exceedingly hard and strong, and very durable in contact with ground or air, hence it is highly valued for fence posts and rails, cross arms and insulator pins for telephone and telegraph lines, carriage hubs and similar turnery, tree nails, etc. It is also valued for fuel and construction purposes, but does not enter largely into the general lumber industry because of the scattered supply and its special uses.

A tree that has been cultivated for so long a time has naturally given rise to numerous horticultural varieties of the parks and gardens. There are also six or seven additional species of *Robinia*, all confined to North America and very similar to the preceding except that they are smaller trees or even shrubs. The only one of these that is generally known is the clammy locust, *Robinia viscosa* Vent., which may be readily distinguished

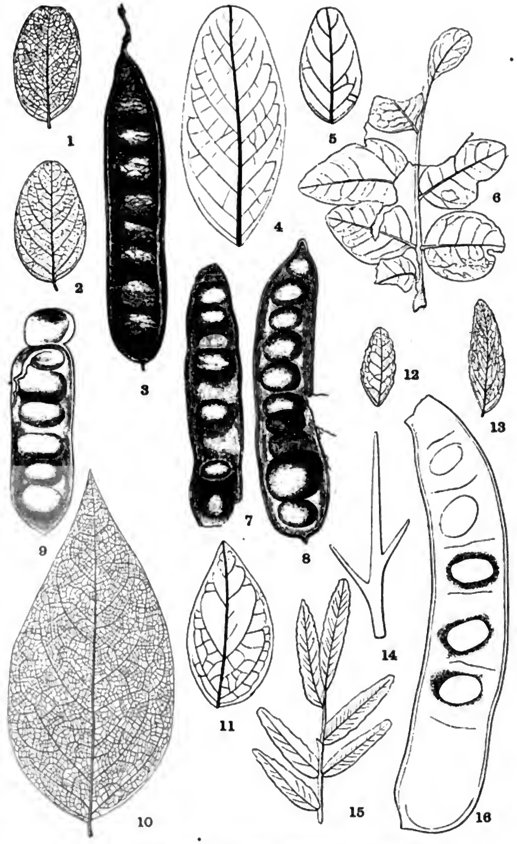

Fig. 1. Fossil remains of *Robinia, Gleditsia and Gymnocladus.*

1–3. Leaflets and fruit of *Robinia pseudacacia* Linn. 4. *Robinia hesperidum* Unger from the Upper Miocene of Croatia. 5. *Leguminosites robiniifolia* Berry from the Upper Cretaceous of South Carolina. 6–8. Leaf and fruits of *Robinia regeli* Heer from the Miocene of Oeningen. 9. *Robinia constricta* Heer from the Miocene of Oeningen. 10. *Gymnocladus dioicus* Koch. 11. *Gymnocladus Casei* Berry from the Miocene of Oklahoma. 12. *Gleditsia allemannica* Heer from the Miocene of Oeningen. 13. *Gleditsia triacanthos* Linn. 14–16. Thorn, leaf and fruit of *Gleditsia Wesseli* Weber from the Lower Miocene of Germany.

by the lack of fragrance of its blossoms. It is a native of the mountains from southwestern Virginia to Georgia, but has been extensively planted in all temperate countries where the climate is not prohibitive and has become extensively naturalized east of the Mississippi as far north as Massachusetts.

The rose acacia, *Robinia hispida* Linn. of the southern Appalachians, a shrub with pink or purple non-fragrant blossoms; and the New Mexican locust, *Robinia neo-mexicana* Gray, a shrub or small tree of the mountain valleys of Colorado, New Mexico, Arizona, and southern Utah, with handsome blossoms, are both favorites outside their natural limits for ornamental planting in both this country and western Europe.

The geological history of the locust is beset with difficulties, the leaflets usually becoming detached before fossilization and both leaflets and pods being often impossible to differentiate from other and unrelated leguminous leaflets and pods. This difficulty of distinguishing between the fossil leaflets of the various genera of Leguminosæ has led paleobotanists to establish a purely form-genus known as *Leguminosites* for leaflets of this sort that cannot be identified with certainty beyond that they are leguminous. Large numbers of species of *Leguminosites* ranging in age from the Upper Cretaceous through the Tertiary are known. Among these are several that might well represent an Upper Cretaceous locust, but such an identity is not conclusive. Certain pods from the top of the Cretaceous in Colorado have been referred to *Robinia* but since this genus has not been recognized with certainty in the succeeding Eocene deposits either in this country or elsewhere, these too must be considered as questionable. Two species of locust have been recognized in the Oligocene of Europe—one in France and the other in Italy. It is in the Miocene, however, that the locust becomes widespread and exceedingly common. At least a dozen different species have been recognized from European deposits of this age and one of these from the late Miocene of central France is so similar to the existing locust of North America that its describer is disposed to consider the two as identical. This form continued to exist in the European area in

Pliocene times. A well marked locust has also been found in the deposits of the lake basin at Florissant, Colorado, but no other North American Miocene form has been discovered.

In addition to the very modern looking Pliocene form already mentioned a second was common at this time along the Mediterranean coast of southern Europe from Spain to Slavonia. There is no evidence that the locust survived the first glaciation in Europe but in North America we find the modern species in the Interglacial deposits of the Don valley in Ontario some distance north of its existing range, and it is also found in the late Pleistocene of Maryland.

### THE HONEY LOCUST (*Gleditsia*)

The black locust is sometimes called the honey locust in New England because of its fragrant nectar-bearing blossoms. The true honey locust is, however, quite another tree and belongs to the family Caesalpiniaceæ, *Robinia* belonging to the family Papilionaceæ.

The honey locust belongs to the genus *Gleditsia*, sometimes spelled *Gleditschia* since it was named by Linnaeus in 1753 in honor of J. T. Gleditsch, a german botanist. *Gleditsia* contains five or six species natives of eastern North America and Asia, and three of these are found in the United States. One, *Gleditsia texana* Sargent, is confined to the Brazos River valley in Texas; a second, the water locust *Gleditsia aquatica* Marsh, is found in our southern states: and the true honey locust, *Gleditsia triacanthos* Linnaeus, a tall graceful tree, ranges from Ontario and western New York to Georgia, Kansas and Texas.

The honey locust is a large tree 75 to 140 feet in height and with a trunk two or three and occasionally as much as six feet in diameter. It is exceedingly graceful in habit with its slender spreading and somewhat pendulous branches forming a broad open head. This together with its tiny leaflets gives it more the appearance of so many of the tropical species of Leguminosæ rather than of a tree of the Temperate Zone, and it is consequently a general favorite as an ornamental and shade tree in all countries with a suitable climate.

The leaves are sometimes slender stalks with 9 to 14 pairs of oblong-ovate leaflets which are never over 1½ inches long and ½ inch wide, and which usually have a slightly, but not apparent, crenulate margin. More usually the leafstalk bears from 4 to 7 pairs of branches each with 8 to 12 pairs of leaflets, which are generally under an inch in length and ½ inch in width. Such leaves in which there is on odd terminal unpaired leaflet on the main stalk or the branches is termed even pinnate. Sometimes, however, the honey locust leaves do have such an odd terminal leaflet, and frequently either the basal or the terminal part of the leaf stalk will lack subordinate leaflet bearing branches and have in their place somewhat larger leaflets on the main stalk with the leaflet bearing branches in the middle part of the leaf stalk. The stipules are small and are soon shed and do not develop into spines as in the black locust. Nevertheless the honey locust is plentifully supplied with thorns. These are large and much branched and are not superficial (epidermal) like the spines of the black locust but are true abortive branches and cannot be readily detached except by cutting.

The flowers appear in the late spring after the leaves. They are not especially conspicuous being greenish-white in color, but are exceedingly fragrant and abundantly nectar-bearing. They are not irregular like a pea blossom as are those of the black locust, but regular and polygamous, *i.e.* some are pollen-bearing and some seed-bearing. The pods are large and flattened, bright brown or purplish in color when mature, and are always more or less curved and twisted as they contract in drying during the autumn. They are from 5 to 18 inches long and about an inch and one half wide. The space between the seeds is filled with a sweet succulent pulp, hence the name honey shucks, and the pods do not split open when the seeds are ripe. The wood is much like that of the black locust and is used for similar purposes.

The water locust is a much smaller tree, with leaves much like those of the honey locust but with somewhat larger leaflets, which are thicker and a darker green. The pods, however, are not much longer than wide with only one or two seeds and without a succulent pulp. The water locust is an inhabitant of river bottoms and swamps and attains its maximum size in the bottom swamps and along stream banks in Louisiana and Arkansas.

No representatives of the honey locust can be recognized with certainty in either the Upper Cretaceous or the Eocene, although there are a number of leguminous leaflets found in the rocks of both of these periods that might well represent its ancestors, in fact a genus called *Gleditsiophyllum* found in both the Upper Cretaceous and the Eocene of North America is suggestively like the honey locust.

A supposed species is recorded from the Oligocene of Europe and there are a number of undoubted Miocene species. Seven or eight have been described, one occurring on the east coast of Asia and the others all confined to Europe, where they are known from Greece and Hungary to France. They were especially abundant in the Miocene woods of Switzerland in the days before the formation of the Alps had been completed. Pliocene records are wanting in both this country and Europe. The modern species appears in the early Pleistocene of Kentucky and an extinct species is recorded from the Interglacial deposits of the Don valley in Ontario.

## THE KENTUCKY COFFEE-TREE (*Gymnocladus*)

*Gymnocladus* is one of those rather numerous and unrelated genera that at the present time is native only in southeastern North America and southeastern Asia, and like the Tulip-tree and the Sassafras it has a single species in each region, scarcely distinguishable from one another, while the ancestral stock has become extinct in the intervening areas. Our American tree is commonly known as the Kentucky coffee-tree or coffee bean, since its seeds were sometimes used as a substitute for coffee, especially during pioneer and Revolutionary times. It is also called the stump tree in certain localities because the leafstalks are often shed after the leaflets and their large size makes it appear that the tree is shedding its twigs. The fresh green pulp of the unripe pods is still used in homœopathic practice and the pulp surrounding the seeds of the Chinese species is detersive and is widely used in its native land as a substitute for soap.

The Kentucky Coffee-tree is a large stately tree from 75 to 110 feet tall with a trunk from 2 to 3 feet in diameter, which, however, generally forks to form three or four main stems within ten or fifteen feet of the ground. The leaves are large, particularly on vigorous saplings and may measure three feet in length by two feet in width. They have a stout leafstalk, a terminal branch and from two to four pairs of lateral branches, each bearing from 6 to 14 pairs of subsessile ovate leaflets, pink at first and turning to a bronzy green at maturity. The stipules, which in *Robinia* become spines, are foliaceous and are soon shed. Nor does the Coffee-tree develop thorns like its close ally the honey locust. The flower clusters are large but scarcely conspicuous except in the young trees. The flowers, while sometimes mixed usually have the pollen bearing ones in separate and larger clusters than the seed bearing ones. The pods are large and hard, dark reddish brown in color, and are sometimes as much as ten inches long and two inches wide. They remain unopened throughout the winter and contain numerous very hard globular seeds, about the size of small marbles, imbedded in the sweet pulp. The wood is strong and coarse grained, heavy but not hard. Like locust wood it resists decay and is occasionally utilized for fence posts, rails, ties and construction, and rarely for cabinet work. The shortness of the butts and the scattered growth usually render the tree immune from the lumberman.

The Coffee-tree prefers rich soil and occurs sporadically but nowhere in abundance from central New York and western Pennsylvania through southern Ontario and southern Michigan to the valley of the Minnesota and southward to middle Tennessee and southwestern Arkansas. It penetrates the prairie country along the bottoms of the larger streams in eastern Kansas, Nebraska and Oklahoma. It is frequently planted in parks in the eastern United States and in western Europe.

The geological history of this tree is unfortunately almost entirely unknown. As it occurs at the present time in both

Asia and North America it must have been present during the Tertiary in the intervening region, as I have already remarked. This implies its presence in not only the Arctic region but in northwestern North America and very probably in Europe. Its former presence on the last continent has not been definitely proven, however. Saporta, many years ago described leaflets and pods from the basal Miocene of France as *Gymnocladus macrocarpa*, but these are usually regarded as more properly referable to some other leguminous genus. Squinabol named a pod from the Oligocene of Italy *Gymnocladus novalensis* but this too is of doubtful identity. An undoubted fossil form has been found in North America. This is *Gymnocladus casei* and it comes from the late Miocene of the "panhandle" region of Oklahoma. It was much like the modern Coffee-tree and is of interest chiefly in showing that at that time the western range of the genus was not as restricted as it is to-day.

There are also fossil leaflets found in the late Miocene of central France that appear to represent a European *Gymnocladus*.

### THE JUDAS-TREE (*Cercis*)

Unlike the great majority of leguminous genera the different species of *Cercis* have simple leaves. These are cordate-orbicular in form, glossy green, palmately 5 to 7 veined and arranged in a two-ranked manner on the long shoots. The pods are small and compressed, lustrously red purple in color, and fall in the late autumn or early winter. There are five or six existing species of *Cercis* although the majority of my readers will be familiar with only the European Judas-tree or its very similar American relative. In addition to these two well known ornamental trees there is a third species in Texas, another on the Pacific coast of North America, and two or three more in southwestern, central, and eastern Asia. Thus *Cercis* is another genus whose distribution suggests the same thoughts as did the distribution of *Gymnocladus*. But in the case of the former more links in the chain have remained until modern times and its distribution to-day suggests what may have been and probably was the distribution of *Gymnocladus* in Miocene times.

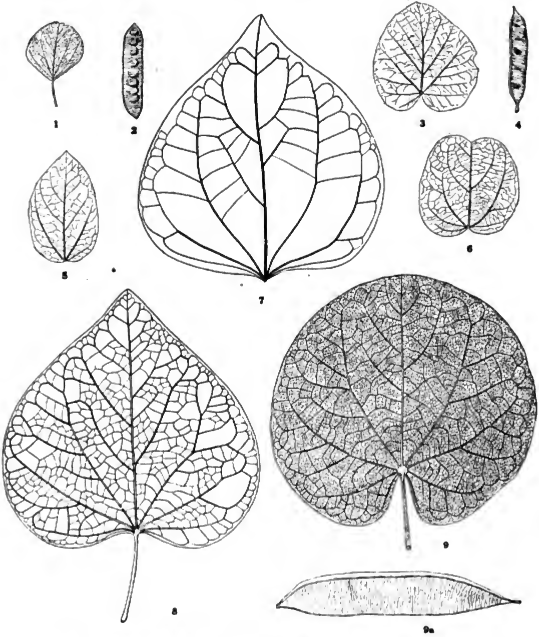

Fig. 2. Fossil remains of *Cercis*. All about one-half natural size.

1, 2. *Cercis antiqua* Saporta from the lower Oligocene of France.
3, 4. *Cercis virgiliana* Massalongo from the Upper Miocene of Italy.
5, 6. *Cercis tournoueri* Saporta from the upper Oligocene of France.
7. *Cercis wilcoxiana* Berry from the lower Eocene of Tennessee.
8. *Cercis çanadensis* Linn. Pleistocene of North Carolina.
9, 10 *Cercis siliquastrum* Linn. Pleistocene of France.

The European Judas-tree, *Cercis siliquastrum* is a native of the south of France, the Spanish peninsula, Italy, Greece and Asia Minor. It is a handsome low tree with a flat spreading head, much utilized in ornamental plantings throughout Europe. Its profuse purplish-pink flowers appear before the leaves. They have an agreeable acid taste and are sometimes mixed with salads or made into fritters.

When originally described the Judas-tree was the tree of Judea, from its supposed origin in Palestine. This name gradually became transposed into Judas-tree and tradition accounted for the latter name by the fact that it was this tree on which Judas Iscariot hanged himself. The tree was frequently figured by the herbalists, and one, Castor Durante, gives a woodcut showing Judas hanging from the branches thus illustrating the popular tradition.

The American tree, *Cercis canadensis*, is much like its European relative in every way and like the latter it is commonly known as the Judas-tree, particularly in ornamental plantings, for which it is extensively used not only throughout our northeastern states but also in western Europe. In its natural surroundings it is perhaps more often known as the Red bud, and is one of the striking objects of the early almost leafless spring woods, its masses of purplish-pink blossoms close to the branches, contrasting with the white of the opening dogwood and forming splashes of bloom in the gray woods. In the latter half of March the traveller through Virginia and the Carolinas can scarcely distinguish from the train window between the blooming peaches and the red buds of the door-yards.

Our Judas-tree grows naturally from the valley of the Delaware and southern Ontario to Tampa Bay, northern Alabama, Mississippi and Texas, and extends westward along the bottoms of the larger streams into the eastern border of the prairie states. It is said that the blossoms are sometimes eaten, although I have never observed this custom. In the days before the prevalence of aniline dyes the branches were sometimes used for giving wool a nankeen color.

The members of this genus are too small for lumbering and the wood has no special uses that I know of, consequently we are not likely to be deprived of the striking beauty of the Judas-tree as we probably should if the wood could be used for bobbins or lead-pencils or boxes.

Fortunately in the case of the Judas-tree a considerable beginning has been made in tracing its geological history, although the inevitable gaps in this history have not all been closed. The oldest known forms come from the lower Eocene and all of these, three in number, are North American, occurring in Tennessee, Mississippi, Montana and Dakota—the last being in a region now one of prairies and bad lands far removed from the habitat of any of the existing forms and showing how the ancestral Judas trees were enabled to migrate across North America in the more humid days that preceded the development of the prairie type of country. A middle Eocene species occurs at Bournemouth on the south coast of England. By succeeding Oligocene times the Judas-tree had appeared at additional localities in Europe where a very characteristic form is found in southeastern France in the lower Oligocene and a second French species occurs at a somewhat later stage of the Oligocene.

We are without information as to whether *Cercis* came down from the north into both North America and Europe or whether America was its original home and it spread across the land bridge in the region of Behring Sea into Asia and thence into Europe. Personally I favor the interpretation that the vast and paleobotanically almost unknown continent of Asia was the original home of the genus from which it spread westward into Europe and eastward across the Behring land bridge into North America. If this is the true story then this migration must have taken place during Upper Cretaceous times even though we have not yet found *Cercis* in the abundant Upper Cretaceous floras, for it is present in the lower Eocene of our Gulf states and in the middle Eocene of the south of England and a journey from Asia would have required a very long time.

The Miocene was pre-eminently the period of hardwood forests, and the ancestral Judas trees seem to have reached the zenith of their differentiation and their most extensive range during these ages that succeeded the Oligocene. Although Asia remains an unknown area we have a glimpse of a small species preserved in the volcanic ash beds of the Florissant lake basin in the heart of the Colorado Rockies, and a second species in Nevada. No less than five species are already known from Miocene Europe, where they are represented as fossils by both leaves and pods. It is especially interesting to note that one of these from the late Miocene of Italy and another closely related form of the same age in France are directly ancestral to the existing European Judas-tree, while a second French species (*Cercis ameliae* Saporta) from the older Miocene of France seems to have been the ancestor of the existing *Cercis japonica* Siebold of eastern Asia. There is little direct evidence of the Judas-tree during the succeeding Pliocene times. Since it occurs both before and after the Pliocene in North America it must have been present at that time. In Europe a single Pliocene species is known from France.

As practically everyone knows, the Pleistocene, which succeeded the Pliocene, was a time of continental ice sheets or glaciers, which played havoc with the floras and faunas, particularly in Europe because of the combination of high mountains and seas along its southern border which effectually barred the ebb and flow of life that took place in Asia and North America with the advance and retreat of the successive ice sheets. During the maximum extent of the ice only a fraction of the Northern Hemisphere was covered and Asia was largely ice-free. The southern limit of the ice in Europe, where the center of accumulation and dispersal was the Scandinavian region, was the German plain. Here in North America the easternmost or Labradoran center of accumulation and dispersal extended its ice fields only as far south as Staten Island on the Atlantic coast, so that there was plenty of room south of the ice for a vast forest and game preserve for the subsequent repopulation of the more northern region.

There were at least three periods of glaciation which were separated by long intervals during which the ice disappeared except in the far north, and it is in the deposits formed during these Interglacial periods that we find the fossil remains of the Judas-tree. Both the American and the European Judas-tree were already in existence. The former has been found in North Carolina and in the Don River valley in Ontario. The latter is rather common throughout France as far north as the site of Paris, and at a number of localities in Italy. Both the American and the European Judas trees frequently depart from the normal orbicular or cordate shape of the leaf, widening them and developing an emarginate apex. This may be an atavistic trait, since several of the ancestral forms appear to have normally had leaves of this shape.

# BOOKS AND CURRENT LITERATURE

Frost Injury.—Those who are interested in the physico-chemical interpretation of plant phenomena and in the general principles of physiological response to environmental changes, will be especially pleased and encouraged by Harvey's[1] account of his studies on tissue-hardening and frost injury. Students of horticulture, etc., who deal with the practical aspects of frost resistance and frost injury in plants will also find much valuable information and stimulation in this paper. The work was well-planned, well carried out and the results are very well presented. A bibliography of 50 titles accompanies the presentation.

The experimentation was largely with cabbage and tomato plants. An idea of the scope of the paper may be had from the following list of the main subheadings. First indications of frost injury and their development in cabbage and tomato, Mechanism of freezing, Growth development in the injected areas, Peroxidyse changes in the injected areas of cabbage leaves, Plasmolytic behavior of tumor cells, Physiological changes in cabbage during the hardening process, Time and temperature factors in acquiring or losing hardiness, Freezing point and expression of cabbage juices, Chemical changes during hardening, Changes in hydrogen-ion concentration of a plant sap on freezing, Changes of reaction on plasmolysis, Potentiometric determination of the changes in hydrogen-ion concentration on freezing, Buffer effect of juice from midrib and rest of leaf, Hydrogen-ion concentration necessary for normal condition of the proteins, Precipitation of the proteins of hardened and nonhardened cabbage on freezing, and on addition of acid.

A significant point is that "wax on the leaf surface prevents the inoculation [by ice-crystals] of the undercooled tissue and thus prevents injury from freezing," when the temperature is not too low or the exposure too long. The tissue liquids are capable of much undercooling and water on the surface of the leaf has little of this capacity; hence if water occurs on the surface it freezes before the tissue liquids and ice crystals apparently grow into the tissues through the larger openings and so start crystallization within. Freezing first occurs in localized areas, with the filling of the gas spaces with liquid. Another important point here emphasized is that frozen cells in leaves of cabbage, etc., are stimulated to later growth and the development of enormous tumors "similar to those shown in pathological conditions, but without the presence of bacteria." (It is remarkable that plant pathology seems to be generally regarded as dealing exclusively with diseased conditions due to bacteria, fungi, etc., as if diseases not related to the commonly studied parasites were not accompanied by pathological conditions! To the reviewer these intumescences that follow partial and local freezing are just as truly pathological phenomena as they would be if they happened to result from bacterial invasion.) This hypertrophy is considered as perhaps primarily related to a partial precipitation of the protein content of the cells, as a result of freezing, and "this precipitation results in an increase in the permeability of the cells to water, and in [an increase in] the ability of the cells to hold sugars." The tumor cells show lower values of the freezing-point lowering than do the rest of the leaf cells, but they contain more sugars, perhaps in chemical combination and consequently not effective to lower the freezing-point. Hydrogen-ion concentration is increased in the tissue liquids as a result of non-lethal freezing, and this,—together with alterations in salt concentration,—is regarded as a main primary cause for the precipitation of proteins and the subsequent tumefacient hypertrophy. Apparently hardening (by exposure to low, but nonfreezing, temperatures) is effective by altering the proteins so that they will be less readily precipitated on freezing. The effects of desiccation, freezing, and plasmolysis are considered to be similar, in that all these processes cause changes in the hydrogen-ion and salt concentration." This last statement is of special interest as a principle of general physiology; the similarity of these influences (and poisoning, as by bacterial excretions and other materials, as the author might as well have added) becomes more and more emphasized from many points of view, as physiology progresses. —B. E. LIVINGSTON.

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[1] Harvey, R. B. Hardening process in plants and developments from first injury. Jour. Agric. Res. **15**: 83-111. 3 figs. (showing graphs), Pl. 7-11 (halftones) and A (colored). Oct. 14, 1918.

CLIMATE AND PLANT GROWTH.—Investigations by Sampson[1] were undertaken for the purpose of comparing climatic requirements of important plant types and of relating quantitatively the growth and behavior of these plants with various physical conditions of their environment. The plants employed were Canadian field pea (*Pisum arvense*), wheat (*Triticum durum*) and mountain brome grass (*Bromus marginatus*). These investigations were carried out in the years 1913 to 1916 at three stations located on the Wasatch Mountains near the Great Basin Forest Experiment Station. Three plant associations, oak-brush, aspen-fir and spruce-fir, were represented at elevations of 7100, 8700 and 10,000 feet respectively. Meteorological data were recorded, summarized and related to growth, water requirement and certain physiological functions of the plants studied. The plants were grown in sealed cans.

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[1] Sampson, Arthur W. Climate and plant growth in certain vegetative associations. U. S. Dept Agric. Bul. 700. 1918.

Some of the main characteristics of the three type zones were that the mean annual temperature increased from the highest to the lowest station, normal annual precipitation was greatest in the aspen-fir association and evaporation during the growing season was greatest at the oak-brush station. Evaporation was almost as great at the spruce-fir station because of high wind velocity there. The duration and intensity of sunshine were practically the same and barometric pressures were nearly constant for each station, though of course differing in actual amounts due to differences in elevations.

It was found that the plants matured more rapidly as the efficiency of the heat units increased. In the three associations studied, wheat and peas reached full maturity only at the lowest station. Water requirement determinations were in good relative agreement with rates of evaporation, each being greatest in the oak-brush and least in the aspen-fir association. The total length of leaves and the total amount of dry weight produced were greatest in the aspen-fir association. The rates of these two plant processes varied inversely with the evaporation rates. Stem elongation was greatest at the oak-brush station and least at the aspen-fir station. There seemed to be a direct relation between this plant process and temperature, while apparently evaporation had little influence. Dry weight per unit leaf area, however, seemed to vary inversely with the evaporation.—Earl S. Johnston.

## NOTES AND COMMENT

Professor Elizabeth F. Fisher, of the department of Geology and Geography at Wellesley College, has prepared a brief volume entitled Resources and Industries of the United States (Ginn and Company). Although intended for use in secondary schools the book contains such a complete and interesting account of our natural resources and the industries that have grown out of them that it may well be read with pleasure and profit by those who are old enough to have received much drier instruction in geography. The plant and animal industries have received their full share of attention and the book is well provided with maps of rainfall, soils and crop distribution.

The Macmillan Company have added to their Rural Science Series a volume on Peach-Growing, by Mr. H. P. Gould, of the Bureau of Plant Industry ($2.00). This is a very thorough and practical treatment of the handling of tree, orchard and crop. Particular attention is given to the selection of suitable orchard sites, the proper pruning at different ages, and the control of diseases. The ill-informed consumer of this fruit will be surprised to learn that 417 varieties are in common cultivation in the United States.

Dr. P. A. Rydberg announces the publication of a small volume containing the keys from his Flora of the Rocky Mountains and Adjacent Plains. This will find use as a handy field book and check list. The plants of Colorado and adjacent states have now received such exhaustive analysis by taxonomists that there are many cases in which it is easier to make doubt-stilling determinations by the use of keys alone than by the aid of manual and herbarium.

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# THE EFFECT OF IONS OF NaCl AND $CaCl_2$ UPON THE ELECTRICAL CONDUCTIVITY OF CERTAIN COLLOIDAL MIXTURES

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## PART I

The experiments described in this paper were suggested by the discovery of Professor Osterhout that the permeability of plant tissues to various ions could be determined by measuring the resistance offered by the tissue to an electric current. A description of his methods first appeared in 1912[1] and since that time he has reported numerous additional determinations of the effect of a variety of substances upon permeability.

The method employed by him is now well known, but for the sake of clearness it may be well to give a brief description of it. He allowed an alternating high tension electric current to pass longitudinally through a stack of discs cut from the fronds of a species of *Laminaria*. Each disc was covered with a film of sea water, which remained after the excess had been drained off, and the stack of discs was held rigidly by a rack of glass and hard rubber so that the two electrodes were pressed firmly against either end. He found that a cylinder of tissue of this description gave a resistance which was fairly constant and considerably higher than the resistance offered by a cylinder of dead tissue or a similar volume of sea water. He considered this resistance to be an indication of the hindrance offered to the passage of the sea water ions by the living protoplasm. This is undoubtedly true since the ions must pass from one electrode through all the discs of tissue to the other, and he demonstrated that the film

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[1] **Osterhout, W. J. V. The Permeability of Protoplasm to Ions and the Theory of Antagonism. Science 36: 112. 1912.**

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DECEMBER, 1918

of water on the outside of the tissue could only account for a very small fraction of the conductivity. In other words resistance is inversely proportional to permeability.

His next step was to transfer the cylinder to a sodium chloride solution having the same specific conductivity as sea water. After washing the discs thoroughly in this he removed them, drained off the excess and took a series of resistance readings. He found that there was an immediate fall, which up to a certain point was reversible. A solution of calcium chloride of the same specific conductivity as sea water gave an increase in resistance up to a certain point which was reversible. From this he concluded that NaCl increases permeability and $CaCl_2$ decreases it. Later he showed that all monovalent salts act similarly to NaCl and all polyvalent salts similarly to $CaCl_2$. Moreover anaesthetics added to sea water decreased the permeability. Another significant fact was the effect of a balanced solution of NaCl and $CaCl_2$. A solution of this character gave no change in permeability whatsoever, *i.e.*, gave a result similar to that in pure sea water. Antagonism would seem to give the only plausible explanation of this phenomenon. In any case it is of prime importance to determine the rôles played by the different parts of the cells involved in the process, and to determine if possible whether the facts are explainable on a purely physical or chemical basis.

The results just mentioned were brought to the writer's attention in a course given by Professor Benedict of the University of Cincinnati and at his suggestion and under his supervision, the experiments described below were carried out. The purpose of these experiments was to show if possible the rate of penetration of ions of NaCl and $CaCl_2$ into cylinders of certain non-living colloids; and to demonstrate the presence or absence of these phenomena which attended the experiments with living material carried out by Osterhout. In brief the questions which the writer attempted to answer were these: Will a cylinder of colloidal material permit ions of one salt to penetrate faster than those of another? In a mixture of two salts, commonly considered to be antagonistic to one another as regards their effect upon permeability, will the ions of one prevent in any degree the ions of the other from entering? The bearing of these questions upon any theory of permeability is obvious.

That either of these questions might be answered in the affirmative seemed fairly possible in view of the work of several investigators, notably that done by Robertson and Miyake[2] upon the influence of alkali and alkaline earth salts upon the rate of solution of casein by NaOH. Moreover J. C. Philip[3] reports cases where the coagulation of colloidal material in mixtures of chlorides of a monovalent and polyvalent metal is not explainable unless the effect of the two is considered to be antagonistic.

### *Method*

In the experiments described here the salts used were the "Tested Purity" brand as sold by Eimer and Amend, and the agar and gelatine were the best commercial brands. Resistance measurements were made in the usual manner with a Wheatstone Bridge set-up using a telephone as detector and a small induction coil as the source of current. During the latter part of the work a variation of this method was employed for convenience sake, which in no way had a different effect upon the final values obtained. The cylinders of colloidal material, while being measured for their resistance, were held in a rack similar to that employed by Osterhout. In making up solutions double distilled water was used having a specific conductivity of less than $2 \times 10^{-6}$ reciprocal ohms. Since this factor was practically constant in all the readings, the conductivity of the water was not subtracted from that of the material dissolved or bathed in it. All readings were taken at temperatures between 18° and 18.5°C. A fluctuation of 0.5° was shown to be within the limits of error from other sources.

Three different classes of colloidal material were used; first 15% gelatine in water, second a mixture of 1 gram of agar and

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[2] Roberston, T. B. and Miyake, K. The Influence of Alkali and Alkaline Earth Salts upon the Rate of Solution of Casein by Sodium Hydroxide. Journ. Biol. Chem. **25**: 351. 1916.

[3] Philip, J. C. Physical Chemistry. London, 1910.

10 grams of gelatine in 100 cc. water, and third a mixture of 3 grams agar, 15 grams gelatine and 2 grams of sifted whole wheat flower in 280 cc. of water. These proportions were found by experimentation to give the proper consistency of gel for convenient handling, and yet be fluid enough to give fair electrical conductivity. It was found that in the case of gelatine for instance the conductivity varied directly with the amount of water present in it. This can be accounted for on the basis of increasing ionization with dilution. Philip[4] points out that in colloidal solutions the size of the aggregate molecules decreases with dilution, and since it is the entire particle in the case of colloidal solutions, which carries the electrical charge, dilution by increasing the number of particles would increase the conductivity.

In practice a cylinder of gel 11 x 53 mm. was employed. Its diameter was identical with the diameter of the electrodes. By compression in the rack its length was decreased to 50 mm. and a good contact at either electrode secured. The resistance of the cylinder when freshly prepared was first determined and it was immediately immersed in the solution to be tested. Two solutions and mixtures of the two were used, NaCl 0.52 M and $CaCl_2$. 0.278 M. These were the concentrations employed by Osterhout and each gave a conductivity equal to sea water. At intervals the rack was removed from the solution, drained and resistance measured. This was continued until the resistance of the gel became identical with that of the solution under consideration. Curves were then plotted with the resistance in ohms as ordinates and minutes as the abscissae. The determinations of each individual combination were repeated many times and on the whole remarkably consistent results were obtained.

### *Results and discussion*

For the sake of convenience in the description of the results the kinds of colloidal material will be designated by the numerals I, II and III, corresponding to the order in which they are

[4] Philip, J. C. *loc. cit.*

described above. The three different classes of material gave practically the same kind of resistance curves. There was greater variation in the case of colloid III, doubtless because of the presence in it of the whole wheat flour with its undetermined electrolytes. In the following curves, which are typical, the points just made are well illustrated. The rate of penetration of the ions is at first very rapid, the resistance often falling 1500 ohms in the first minute, then it gradually slows down and the final fall of 50 to 100 ohms is only accomplished after some forty hours.

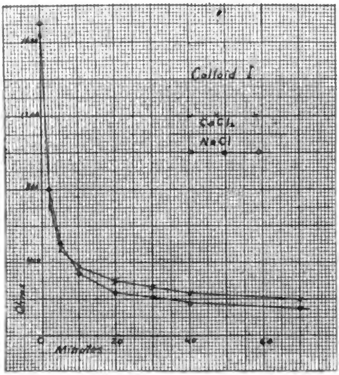

FIG. 1

During the first few hours there is an average difference of 20% between the readings with NaCl and $CaCl_2$ as in figure 1. The diffusion of Na ions is faster than the diffusion of the Ca ions because of the greater adsorption of the latter by the gelatine. This adsorption occurs first at the surface of the colloid

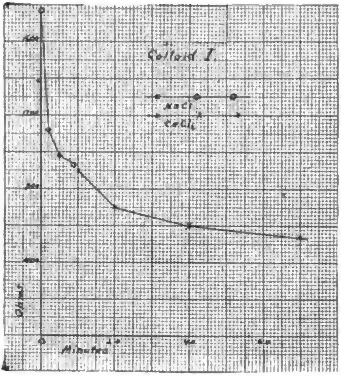
Colloid I.
NaCl
$CaCl_2$
Ohms
0
Minutes
20
40
60

FIG. 2

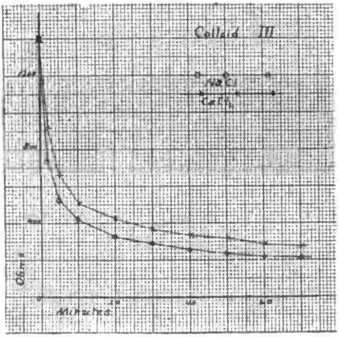
Colloid III
NaCl
$CaCl_2$
Ohms
0
Minutes
20
40
60

FIG. 3.

where the salt ions penetrate and the effect is to hinder the further entrance of both anions and cations.

In figure 2 the cylinder was immersed first in NaCl and after ten minutes $CaCl_2$ was substituted. The second part of the curve shows no effect of the Na ions which are already present,

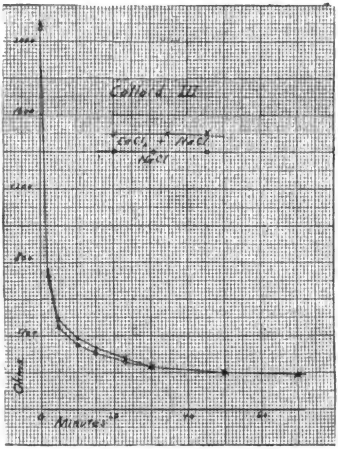

FIG. 4.

and there is no indication that the ions of the second salt are in any way prevented from entering by the ions of the first salt.

Figure 3 shows with the colloidal mixture the more rapid penetration of the NaCl ions. Fenn[5] comes to a similar conclusion but attempts no explanation.

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[5] Fenn, W. O. Similarity in the Behaviour of Protoplasm and Gelatine. Proc. Natl. Acad. Sci. **2**: 539. 1916.

When the NaCl and $CaCl_2$ solutions are mixed in the proportions of 1000 to 15 and the rate of penetration into colloid III measured, a curve is obtained as shown in figure 4. Along with this curve is plotted a curve showing the effect of NaCl alone, making the conclusion obvious. This experiment was repeated using other proportions and in every case the curve followed a course between that obtained for either salt alone, the preponderant salt having the greater effect. Apparently the inhibitive effect of the adsorbed Ca ions is no greater for ions of one salt than for another.

### *Summary of Part I*

Cylinders of colloidal gel such as gelatine, or mixtures of gelatine, agar and whole wheat flour, are readily penetrated by ions of NaCl and $CaCl_2$, the initial rate of penetration is not the same for both salts; after several hours the rates become identical. At the beginning the NaCl diffuses more rapidly than the $CaCl_2$, the ratio of the two rates being approximately 10:8. Because of the greater adsorption of the cations in the case of $CaCl_2$ the diffusion of ions is hindered to some extent. This occurs at the surface of the colloid and may help to account for Osterhout's decrease in permeability using calcium salts.

When one salt is allowed to penetrate the colloid for a time and then a second salt substituted, the rate of penetration of the ions of the latter seems to be unaffected by presence of the former.

A mixed solution of NaCl and $CaCl_2$ gives a curve of resistance fall similar to that of either of the constituents alone. It approaches in value more nearly the curve of the predominant salt.

The ions of NaCl and $CaCl_2$ do not antagonize one another as regards their penetration into certain colloidal gels, notably gelatine, and mixtures of gelatine, agar and whole wheat flour.

## PART II

The electrical determination of the penetration of ions into gelatine is valuable as an index of the rate of diffusion of those ions, but it does not show (except very indirectly) the actual effect of those ions upon the colloidal particles. The resistance offered by a cylinder of gelatine is so great compared with that offered by a similar volume of 0.52 M NaCl that, when the two are mixed, the part played by the former is wholly lost in the enormous effect produced by the latter. The importance of this fact was not fully realized by the writer until his attention was called to the results obtained by Fenn.[6] He measured the precipitating effect of 95% alcohol upon gelatine to which had been added various substances. He showed that any electrolyte added to pure gelatine in increasing concentrations decreased the ability of the alcohol to cause precipitation; and that electrolytes

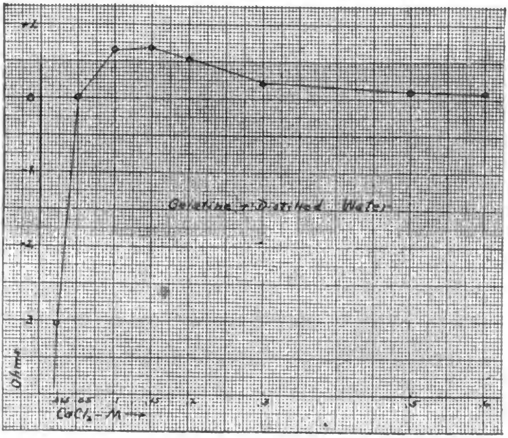

Fig. 5

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[6] Fenn, W. O. Salt Antagonism in Gelatine. Proc. Natl. Acad. Sci. **2**: 534, 1916.

may be divided into three classes as regards their effect upon each other in relation to the gelatine. Members of any one group give additive effect when mixed together. But when two individuals from different groups are mixed the effect is antagonistic. This antagonism is between unadsorbed ions bearing opposite electrical charges, and is made possible by the tendency on the part of the gelatine to adsorb more of one kind of ion than of the other.

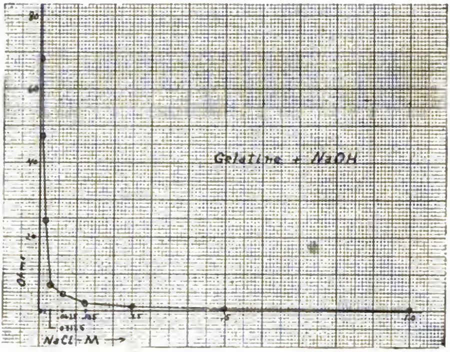

Fig. 6

He showed that NaCl and $CaCl_2$ belong to different groups and that mixed in proper proportion and concentration they caused precipitation without the addition of any alcohol whatsoever. From this he postulated his theory that antagonistic salts produce a precipitate or state of aggregation of an isoelectric nature in the protoplasm, and that protoplasmic permeability is directly dependent upon the amount of this precipitate, being inversely proportional to it.

Fenn's hypothesis as stated above does not explain why *every* salt should not increase permeability. However, in a second paper[7] he describes further experiments and states their application to protoplasm. To explain the decrease in permeability caused by $CaCl_2$ he postulates a condition of protoplasm in which there is a predominance of anions. This may be brought about in gelatine by the addition of a small amount of NaOH, which belongs to the third group of electrolytes and antagonizes both NaCl and $CaCl_2$. The gelatine plus NaOH bears a negative charge because of the greater adsorption of the sodium ions. When either NaCl or $CaCl_2$ are added antagonism occurs but not at the same molecular proportions, for calcium ion is much more readily adsorbed than the sodium ion. The latter even at low concentrations are numerous enough to overcome the OH ions and transform the charge of the gelatine to the positive side of the isoelectric point. The Ca ions on the other hand are actively adsorbed and those that remain are not numerous

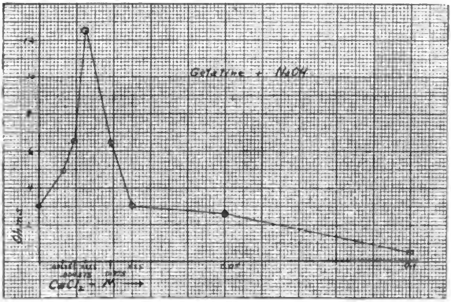

FIG. 7

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[7] Fenn, W. O. Similarity in the Behaviour of Protoplasm and Gelatine. Proc. Natl. Acad. Sci. **2**: 539. 1916.

enough to overbalance the OH ions until the concentration is considerable. As this point is approached the precipitability is of course increased and in the case of protoplasm the permeability is decreased. After the isoelectric point is attained the preponderance of cations causes the gelatine to behave as though only one salt were present, that is the precipitability decreases.

Fenn showed that this process actually did occur in gelatine and he demonstrated a remarkable likeness between his curves of precipitability and Osterhout's[8] curves plotted from the changes in the electrical resistance offered by discs of *Laminaria* frond. To complete the analogy it is necessary to assume that in the case of *Laminaria* the effect of time is to increase the concentration of the salts in the tissues. In this connection Fenn also predicted that the changes in electrical resistance offered by the gelatine, as the salt concentration is increased, will give curves which are also similar to those of Osterhout's. The experiments which the writer will now describe were undertaken to test the truth of Fenn's prediction, namely, that the electrical resistance of the gelatine is greatest at the isoelectric point, where the least alcohol is needed for precipitation.

### *Method*

The gelatine used was one of the best commercial brands but proved rather unsatisfactory because of the unavoidable high electrolyte content. In a 1.5% solution the gelatine gave a specific conductivity twenty times as great as once distilled water, which had a specific conductivity of approximately $2 \times 10^{-6}$. In practice a series of test tubes was prepared each containing the gelatine solution plus the salt solution, the effect of which was to be determined. For each tube was prepared a control containing all the constituents with the exception of the gelatine, for which distilled water was substituted. The specific resistance was measured by means of the apparatus described in the first part of this paper and the readings were corrected for temperature. The difference between the resistance of any tube and its control represented the resistance due to the gelatine alone. This was of course a negative quantity in the case of pure gelatine and its control, but for all salt concentrations above 0.005 M NaOH it was positive. This is to be expected since the colloidal particles obstruct the path of the ions; and the effect is overbalanced by the native gelatine ions only when the added salt concentration is very low.

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[8] Osterhout, W. J. V. The Permeability of Protoplasm to Ions and the Theory of Antagonism. Science **35:** 112. 1912.

Since the purpose in performing these experiments was merely to demonstrate the connection between precipitability and conductivity, only the most elementary of Fenn's combinations were attempted. NaCl in concentrations from 0 to 1.0 M were added to the pure gelatine solution and to gelatine solution plus NaOH. $CaCl_2$ was also added at similar concentrations and curves plotted for the specific resistances due to the gelatine. Sample curves are shown herewith. It will be noted that the curves in which the NaOH is lacking exhibit the character which has been previously pointed out, *i.e.*, that until the higher salt concentrations are reached the resistance values for the gelatine are negative. This lack of resistance is due to native electrolytes in the gelatine which provide enough ions to overbalance the inhibitive effect of the colloidal particles. When the curves are examined with this fact understood, they are seen to agree with Fenn's hypothesis for the resistance of the gelatine does decrease as the salt concentration increases.

The curves of the resistance offered by gelatine plus NaOH are remarkably similar to Fenn's curves of precipitability. The isoelectric point where the resistance is greatest, occurs when the ratio of $CaCl_2$ to NaOH is 0.0125 M: 0.005 M. In the case of NaCl the isoelectric point occurs before the concentration reaches 0.00625 M and since this is the lowest concentration used, the curve of resistance falls from the start, as did Fenn's curve of precipitability.

It is possible then to make the assumption that in the case of protoplasm electrical conductivity and hence permeability is determined by the presence of a precipitate, which in turn is dependent as to its quantity upon the relative proportions of certain electrolytes. Moreover these electrolytes may be classified into three groups as regards their effect upon one another in relation to this precipitate, said effect being due to antagonism between unadsorbed + and − ions.

### *Summary of Part II*

Determinations of electrical resistance were made of solutions of gelatine to which had been added salts in varying concentrations. The purpose of these determinations was to show whether electrical resistance varies directly with the precipitability of the gelatine as determined by Fenn.

The electrical resistance of the gelatine was found to vary directly with the precipitability, which is greatest at the isoelectric point.

The isoelectric point occurs when the unadsorbed + and − ions of the added salts balance one another.

It is assumed that balanced solutions owe their effectiveness to the fact that the protoplasm adsorbs from them equal numbers of + and − ions thus bringing the condition to the isoelectric point, at which there is greatest ionization of the protein, greatest amount of precipitate and greatest (or normal) permeability.

# THE ENDEMIC PALMS OF HAWAII: PRITCHARDIA

VAUGHAN MACCAUGHEY

All of the native Hawaiian palms are endemic, and are members of the genus *Pritchardia*. The exact botanic status of a number of forms is still unsettled, but it is entirely evident that *Pritchardia* in Hawaii has manifested the same polymorphic tendencies in evolution that characterize many other distinctively Hawaiian plant and animal genera.

The writer has been particularly interested in field studies of the Hawaiian species of *Pritchardia*, and in the recognition of their large ecological variations. It is his mature conclusion that all of the Hawaiian forms have evolved from one or possibly two primitive ancestral stocks; that new forms are developing at the present time; and that many of the described "species" are in reality only sub-species or varieties.[1] The descriptions in the literature have been in many instances, based upon very limited herbarium material, and have by no means taken into full account the ecologic factors.[2] These latter are of unusual importance in any critical study of Hawaiian organisms.

The genus was established by Seemann and Wendland in Bonplandia (9, 1861, p. 260 and 10, 1862, pp. 197, 310 t. 15). The generic characters were defined as follows:

> Flores hermaphroditi, sessiles. Spathæ 00 cylindricae, subcompletae. Perigonium externis campanulatum, 3-denticulatum, interius 3-phyllum, phyllis basi truncato-cordatis cum staminum cylindro connatis, deciduis, præfloratione valvata. Stamina 6, subæqualia; filamentis in tubum brevem connatis, antice liveris lanceolatisque; antheris oblongo-lanceolatis dorso affixis. Ovarium 3-loculare, ovalis

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[1] For an extended discussion of the evolution of species and varieties in the Hawaiian fauna and flora see Vaughan MacCaughey, Outstanding Biological Features of the Hawaiian Archipelago, American Naturalist, in press.

[2] See Forests of the Hawaiian Islands, Vaughan MacCaughey, The Plant World **20**: 162–166. June 1916.

basi affixis. Styli apicales, uniti. Drupa baccœformis, 1-cocca, endocarpio tenui. Albumen æquabile, per chalazum et raphem in latere ventrali lævissime impressum. Embryo dorsale, paululum supra basim positum.—Arbores erectae, inermes, frondis flabelliformis, palmatisectis, petiolis inermis; spadicibus lateralibus, longe pedunculatis paniculo-duplicatovel triplicato-ramosis.

The genus was named in honor of William T. Pritchard, British consul at Fiji in 1860. It belongs to the tribe Corypheœ, and is distinctive of the islands of the Pacific. If *Colpothrinax* be incuded in the genus, the range is extended to Cuba. *Colpothrinax* is distinguished from the true *Pritchardia* by the fact that the former has an ovary made up of distinct carpels, the latter does not. The inclusion of *Colpothrinax* with *Pritchardia*, which is not favored by the writer, raises some very interesting problems in geographical distribution, somewhat beyond the scope of this paper. The writer views *Pritchardia* as a well-defined Polynesian genus, which has reached its highest development in the Hawaiian Archipelago.

The exact number of species comprising the genus is unknown. The following forms are at present recognized in the literature[3] but the specific status of a number of the Hawaiian "species" is open to serious question.

*P. arecina* Beccari; *P. Beccariana* Rock; *P. eriphora* Becarri; *P. eriostachia* Beccari; *P. Gaudichaudii* H. Wendland; *P. Hillebrandi*

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[3] In addition to the 16 species listed, there are numerous names either of dubious significance or synonyms, in the literature Some of these are:

*Pritchardia aurea* H. Lind.—?
*P. borneensis* H. Lind.—Licualae sp.
*P. Cusiniana* H. Lind.—Livistona sp.
*P. filamentosa* H. Wendl.—*Washingtonia filifera*. H. Wendl.
*P. filifera* Lind.—*Washingtonia filifera.*
*P. grandis* H. Bull—*Licuala grandis* H. Wendl.
*P. grandis* H. Veitch—*Licuala orbicularis* Becc.
*P. insignis* Becc.—cultivated in botanic gardens, Georgetown, Demerara.
*P. macrocarpa* H. Veitch H. Lind—?
*P. Maideniana* Becc.—cultivated.
*P. moensii* Hort.—?
*P. nobilis* Hort.—?
*P. pacifica* var. *Samoensis* Becc.—Samoa.
*P. robusta* Hort.—?

Beccari; *P. lanigera* Beccari; *P. Martii* H. Wendland; *P. minor* Beccari; *P. Pacifica* Seemann & H. Wendland; *P. pericularum* Wendland; *P. remota* Beccari; *P. Rockaina* Beccari; *P. Thurstonii* F. v. Mueller and Drude; *P. Vuylstekeana* H. Wendland; *P. Wrightii* Beccari.

The geographical distribution of these 16 forms is as follows:

SOUTH PACIFIC OCEAN

| | |
|---|---|
| Fiji, Tonga, Samoa | *P. Pacifica* |
| Fiji only | *P. Thurstonii* |
| Paumotu Archipelago | *P. pericularum*<br>*P. Vuylstekeana* |

NORTH PACIFIC OCEAN

Hawaiian Archipelago:

| | |
|---|---|
| a. All high islands of group | *P. Hillebrandi*<br>*P. Gaudichaudii*<br>*P. Martii* |
| b. Hawaii only | *P. Beccariana*<br>*P. eriostachia*<br>*P. lanigera* |
| c. Maui only | *P. arecina* |
| d. Oahu only | *P. Rockiana* |
| e. Kauai only | *P. minor* |
| f. Low islets only (Nihoa & Laysan) | *P. eriophora*<br>*P. remota* |

WEST INDIES

| | |
|---|---|
| Cuba only (*Colpothrinax*) | *C. Wrightii* |

*P. Martii* is recorded as in cultivation in southern California. Seeds of other species have been sent, at various times, to botanical gardens throughout the world, where the trees may be seen in cultivation, and often erroneously labelled.

The name applied by the native Hawaiians to all species of *Pritchardia* is *loulu* and this convenient designation will be used generally in the subsequent remarks. The *loulus* are abundant in many parts of the islands, especially in those parts of the rain-forests that have not been ravaged by man or live stock. In the Punaluu Mountains, Oahu, for example, there are hundreds of trees; every ravine wall is marked by one to many clumps of this characteristic and easily recognized palm. It usually does not grow on the extreme ridge-crests or summit peaks, but on the slopes, where its footing is more secure and it is protected somewhat from the strong winds.

The vertical range of the *loulu* extends from sea-level to an elevation of about 5000 feet. These are the extremes, however, and the bulk of the range lies between 1000 to 3000 feet, in the middle forest zone.[4] In early times the palms were very much more numerous than now near the sea and at the lower levels. They have been almost wholly exterminated from the lowlands by man and live-stock, as have many other Hawaiian beach and lowland plants. The upper level coincides with that of the middle forest zone; on Maui and Hawaii, which rise high above this zone, the *loulus* do not ascend above 6500 feet.

The *loulu* finds the optimum conditions for its development in the level portions and ravine bottoms of the rain-forests, where it is protected from the winds, where the soil is deep and rich, and where it can rear its crown above the surrounding vegetation. In these situations it attains a height of 30 to 45 feet with a trunk 12 to 16 inches in diameter, and a magnificent crown of massive foliage.

The normal water requirements of the *loulu* are a substratum well saturated and a humid atmosphere. It will not grow in situations where the water is stagnant, nor where the soil is xerophytic. It is able to maintain itself, however, in rather dry atmospheric conditions, as on Nihoa and Laysan. The palms on these low, wind-swept islets are stunted and give ample evidence of the uncongeniality of their environment. In the rain-forests the soil is water-soaked throughout the year.

Clumps of aged *loulu* palms are plentiful along the windy precipices of the various islands, at altitudes of 1800 to 3500 feet. In these inaccessible habitats the palms maintain a precarious footing. They are conspicuously dwarfed and wind-formed, and are usually under 8 to 10 feet in height. How the palms reached these remote hanging valleys is difficult to understand, as no natural agency is known whereby seeds could have reached these stations. The palms have evidently occupied these stations for very long periods of time, and may be the vestiges of much larger primitive groves.

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[4] Rock states (Indig. Tree Haw. Is. p 99) that "the native Pritchardias . . . are found only at an elevation of about 2000 to 3000 feet in the west or rain-forest zone, though occasionally *P. Gaudichaudii* occurs near the beach and often at 1000 feet elevation." This statement is scarcely accurate, for various forms of *Pritchardia* habitually occur both above and below the 2000 to 3000 feet zone. Like many other native Hawaiian plants, the loulus in ancient times undoubtedly has much larger ranges than at present. Regions in which the *loulu* palms are abundant today are: Waialeale, Kauai; Koolau Mountains, Oahu; mountains of East Molokai and West Maui; windward slopes of Hale-a-ka-la, Kea, and Loa, and the Kohala Mountains, Hawaii.

The life period of the *loulus*, like that of many other Hawaiian trees, is not known with accuracy. All plant growth in the rain-forests is very slow, and the *loulu* gives every indication of conforming to this general rule. The average mature *loulu* is probably at least 50 years old, and a large proportion of them are probably double or treble that age. The active erosive agents along the ravine wall, precipice, and stream-way are evidently the chief factors in terminating the life of the tree. It is probably true that the *loulu* rarely dies of old age, but is destroyed by torrent, wind, or landslide.

The dissemination from higher to lower levels is easily understood. The heavy, hard, durable drupes drop from the tree, and are carried by their own weight down the steep slopes which characterize the regions occupied by the rain-forests. They may either lodge in irregularities in the slope or (as very commonly occurs) roll down into the stream. They are carried along the streamway, finally lodging and germinating. Hence it is not difficult to account for the *loulu* along the valley slopes and streams.

The young *loulu* palm is shade tolerant. For many years it must grow under the canopy of the rain-forest. Eventually, however, it lifts its crown of great stiff leaves and receives unobstructed illumination. The mature palms are intolerant and do not grow well under the shade of taller trees. In looking across a wooded ravine all of the mature *loulus* are easily perceived, because they stand out plainly above the other vegetation.

In view of the unsettled status of Pritchardian species in Hawaii the writer feels that a general statement of the *out-*

*standing features*, common to all the forms, will be of greater value and interest to fellow-workers than any attempt to further multiply the descriptions of suppositious specific differences. The following characters apply to the Hawaiian forms of *Pritchardia:*

Roots: The root system is simple and compact. The roots of a mature tree have a total spread of 6 to 8 feet, although many of the roots are much shorter than this. Most of the roots are densely clustered immediately below the base of the tree. The roots are light brown, brittle cortex and sparingly branched, 0.50 to 0.75 inch diameter, with a tough woody central cylinder. All roots examined by the writer have been notably free from disease or infestation. No economic uses are known for the root among the natives or others.

Trunk: The *loulu* trunk is unarmed, and invariably unbranched. Suckers or offshoots are never produced at the base, although the growth of seedlings close around the base sometimes stimulates the soboliferous effect. The trunk is erect and usually quite vertical, even in wind-swept situations. Along the very windy summit ridges the erosive actions of the steep slope and the positive heliotropism of the crown causes the trees to lean out *against* the wind, rather than to yield to it.

On the steep ravine walls the trunks are often strongly curved at the base, the stem rising from this concave base. This condition is due to the rapid erosion of the ravine-wall and the effort on the part of the plant to prevent itself from sliding down hill. Many woody plants on the steep slopes have this common ecologic character of strongly curved bases. The base, especially of young palms, is sometimes swollen or bulbous, but this character is variable, and its ecologic significance is not known.

The trunk of the mature palm is 4 to 40 feet in height and 6 to 16 inches in diameter. On wind-swept summits the average height of trunk alone is 4 to 5 feet; in protected situations, as in gorges and in the tall forests of Hawaii, the trunk not uncommonly rises to 25 to 35 feet, 20 feet may be taken as an average height. The trunk of *P. Wrightii* Beccari, the Cuban Barrel or

Bottle Palm, now placed with the true Pritchardias, is swollen or bottle-shaped in its lower portion, above this it is slender; the whole trunk rises to 30 to 40 feet.

It is a common experience to find the trunks mutilated by deep gashes or *machete* scars. These are footholds cut by Hawaiians and others who have climbed the trees to gather the leaves or fruits.

The trunk may be naked throughout, or clothed toward the summit with dead leaves and petiole-bases, or clad throughout with old petiole-bases. These latter often remain clinging to the trunk for many years and form a large mass of dead material, usually extending for 2 to 4 feet down below the living crown, and projecting for 6 to 8 inches on all sides of the trunk. This coarse matting is easily stripped off; such action arouses various lepidoptera and other small insects that habitually conceal themselves in these situations.

The bark is grayish or reddish brown. The fissures are shallow, sinuous, not close together, and not confluent. The annular petiole-scars are close-set, not prominent, and soon become indistinct. The bark is relatively thin—about 0.1 to 0.3 inch thick—and very soft and corky. On its dry or leeward side the trunk is usually chalky white, and thus conspicuous for a considerable distance. The windward side is stained and weather beaten. The wood is soft and fibrous. Its color is white, tinged with reddish; it darkens rapidly upon exposure. No economic uses are known for the trunk or wood.

LEAVES: The leaves are terminal. The terminal bud is central and erect, elongate, conical, acuminate, 20 to 35 inches tall, and composed of 6 to 8 young leaves. These are compactly folded upon their own plaitings; the inner ones are creamy-yellow and tender. The writer has often found the apical parts of the bud leaves more or less seriously attacked by aphids and fungi. Unlike the natives in certain other countries, the Hawaiians did not use the succulent terminal bud for food.

There are generally 20 to 35 fully mature living leaves on a mature tree. The fully-expanded leaves rattle in the breeze as though they were made of thin sheet metal, they are so coriaceous. The dead leaves are tough and leathery and are generally rotten at the base, where the moisture collects.

PETIOLE: The petiole is unarmed; 2 to 4 feet long; concave-convex, with sharp edges. The petioles of young plants are much longer and more slender than those of mature plants, and have little or no matting at the base. On old leaves the fibrous matting (vagina) often extends along the margins of the petiole for one-quarter to one-half the length of the latter. The petiole often has a narrow yellow median stripe along the under side. The petiole terminates on the upper face of the blade with a short, strong, semi-circular, pointed ligule, which is auricled at each end. On the under side of the leaf the petiole is prolonged into a suddenly contracting arrow-shaped rhachis about 6 inches long. *P. periculorum* Wndl. of the Paumotu Islands is characterized by dark golden-brown petioles.

BLADE: The leaf-blane is fan-shaped and palmatisect; 3 to 4 feet long and somewhat less in width. The midrib is sometimes quite yellow. The segments number 20, 40 to 60, and are about 1 foot long. Each segment is again slit at the apex into 2 linear-acute lobes. In some forms the lobes are truncate. A fibrous thread about 6 inches long projects from each sinus; in some forms it is short or entirely absent. The apical portions of the leaf segments are stiff and outstanding, not drooping. All segments are connate to about the middle. In some forms the blade is covered underneath, particularly near the base, with a pale-brown dense matted wool. There is great variability as to the extent and density of this wool, and it cannot be relied upon as a systematic character. In many forms the blade underneath is glaucous and glabrous, not woolly, but in the younger state covered with thin, appressed, and soon deciduous scalelets.

The new leaves are clean and unmutilated; the older foilage is often marked by the attacks of insects and fungi, and is wind-beaten. The leaves of the seedling *loulu* are not palmatisect, but are narrow lanceolate, attentuate or acuminate at both ends. They are squamose underneath, with scattered silvery pubescence. They are strongly plicate, but the segments are not free; on slightly older leaves the segments gradually become free as the leaf enlarges. The seedling leaves are 8 to 14 inches long and 3 to 4 inches wide. The seedling usually has 5 to 8 leaves.

In the dense forest which closes both the steep slopes and the less rugged parts of the montane districts, the young *loulu* palms do not have adequate space for lateral expansion. All available space is monopolized by the strongly-competing vegetation. The *loulu* petioles are upright and more or less etiolated. Along the streamways, however, there is more room at least over the stream itself, and in these situations the young *loulus* form beautiful rosettes, 20 feet in diameter and 18 feet high, with maturing leaves at every angle from vertical to horizontal.

The region at the summit of the trunk which is occupied by the leaf-bases is usually a veritable microcosm of epiphytic plants and minor animal forms. A considerable quantity of litter and humus accumulates on the broad upper surfaces of the close-set petiole-bases. In this aerial garden germinate the spores and seeds of various forest plants. Ferns, vines, creepers, and even small shrubs and trees grow thus epiphytically in the palm crowns.

The petioles and trunks often support a rich flora of liverworts, mosses, filmy ferns, lichens, and other minor epiphytes. The blade itself is usually clear and free from epiphyllous forms.

INFLORESCENCE: There are usually 10 to 18 (sometimes more) spadices, in various stages of development. All parts of the inflorescence, except the flowers themselves, are covered with dense scurfy-wool. There is considerable variation as to the quantity and distribution of this wool. The infloresence is a thrice-branching panicle on a long acillary peduncle, enclosed at first in several thick coriaceous, cylindrical spathes. *P. Thurstonii* Drude and several Hawaiian forms are characterized by long slender inflorescences, like fishing-rods, bearing a thyrse-like inflorescence. Usually the inflorescence is 2 to 3 feet long, it continues to develop slowly until all the fruits are mature. The spathes are 5, lanceolate-oblong, furfuraceous externally, and in some forms perfectly glabrous. The ultimate branches of the panicles are 3 to 8 inches long, stout and spreading. Upon these are set the flowers, which are sessile, single, and spirally arranged; there are about 30 flowers to each branch. The flowers are scattered along nearly the whole length of the tortuous, more or less tomentose or woolly branches of the panicle. The bractlets are short and filiform.

The perianth is greenish-yellow; ovary green. The flower is 0.5 inches high and 0.25 inches in diameter; hermaphrodite; coriaceous. The outer perianth is tubular-campanulate, 3-toothed; the inner is 3-parted and with a very short tube which is connate with the staminal cup. The segments are ovate-lanceolate, valvate, and deciduous from the tube. The stamens are 6, spreading, yellow, equal, connate below in a tube or cup, the anthers linear oblong; the free portions at length reflexed. At the base of the perianth, surrounding the style, is an annular nectary. Insects are attracted in considerable numbers by the pollen and nectar, both of which are abundant. The style is 0.25 inches high, single, trisulcate, and attenuate with 3 minute blunt stigmas; deciduous. The ovary is trigonous or 3-lobed, 3-loculed, with 1 erect ovule in each locule.

The young fruit is bright green, glossy, and conspicuously marked with very numerous close-set lenticels. These are light colored and not protuberant. The fruit is somewhat slightly ridged or angled. It bears at its apex the dried remnants of the style and adjacent tissues. The mature fruit is oval, subglobose, or globular, 1½ to 2 inches in diameter, 2 to 3 inches long, and resembling in shape and color a large dark purple plum. The drupe is dryish, with a single central seed or nut. The epicarp is dark purple or black, thin, fibrous, fragile upon maturity and breaking so as to expose the mesocarp. The mesocarp is thick, fibrous, and astringent. The albumen is uniform, horny, snowy-white, smooth, sweetish-fragrant, and slightly impressed on the ventral side by the raphe and chalaza. The embryo is located at the back of the albumen above the base. The albumen is edible, and is considered a great delicacy by the Hawaiians and others who know of its pleasant taste.

There are 30 to 80 drupes to each panicle, but many of these fall while immature, so that old panicles have only 8 to 15 mature drupes.

Bailey, in the Standard Cyclopedia of Horticulture (V: 2810) separates the Hawaiian species from *P. pacifica* on the basis of the color and size of the fruits, designating the Hawaiian forms as "Fruit yellow or red" and those of *P. pacifica* as "black-purple." This is inaccurate, as many Hawaiian Pritchardias have fruit which is black-purple.

The fruits, both green and mature, are eaten by the wild rats. These are introduced species which have become abundant in the forests and have adapted themselves to a diet which is almost wholly frugivorous. The rats do not eat the palm fruits in sufficient quantities to seriously affect the dissemination of the species.

The Hawaiian name for *P. Gaudichaudii* H. Wendl. is *loulu lelo*, for *P. Martii* H. Wendl. is *loulu hiwa*. The word *loulu* is also used by the natives for umbrella; in olden times leaves were used as protection against sun and rain. The Fijian natives make fans (*iri masei* or *ai viu*) from the *Pritchardia* leaves, which are used only by the chiefs. The fans are 2 to 3 feet across and have a border of flexible wood. They are used as sun-shades, as well as to protect from the rain. The foreign umbrellas are called *ai viu* by the Fijians.

The *loulus* were formerly cultivated near native dwellings and settlements throughout the islands. Today one may find remnants—one or two neglected trees, here and there—of these primitive groves. Not only were the albuminous kernels prized as delicacies, but the flexible immature leaves were utilized in the manufacture of hats and woven fans. The leaves were rarely or never used for thatch, save for the construction of temporary shelters in the forest.

As the *loulus* are the only representatives of the palm family which are indigenous to Hawaii, they are peculiarly appropriate for planting as ornamentals. They grow well on the lowlands, even in a rather dry atmosphere, providing they have abundant irrigation. They flower and fruit, apparently as freely as in their native habitats.

## LITERATURE

L. H. BAILEY: Standard Cyclopedia of Horticulture V: 2809–10, 1916.

O. BECCARI: Malesia III: 288–317, 1890.
  Webbia II: 207, 1907.
  Webbia III: 137, 1910.
  Webbia IV: 202–240, 1913.

Flore des Serres. Ghent. vol. 22, 1879, col. pl. 2262.

C. GAUDICHAUD-BAUPRE: Botanique du Vogage atour du Monde . . . sur la Bonits. tab. 58, 59.

HILLEBRAND: Flora of the Hawaiian Islands, 1888, pp. 450–451.

L'Illustration Horticole. Ghent. vol. 21, 1875, col. pl. 161; vol. 26, 1880, col. pl. 352.

VAUGHAN MACCAUGHEY: Trees and shrubs of the Kona-hua-nui region, Oahu. Hawaiian Forester, vol. 13, pp. 28–34, 1916.
  Economic Woods of Hawaii. Forestry Quarterly vol. 14, pp. 696–716, 1916.

C. F. VON MARTIUS: Historia naturalis Palmarum III: 242.

J. F. C. ROCK: Indigenous trees of the Hawaiian Islands, 1913. A new species of Pritchardia. Bull. Torrey Bot. Club. 43: 385–87, 1916.

B. SEEMAN: Flora Vitiensis 273–275.

WILLIAM WATSON: Gardeners Chronicle III, **13**: 332, 1893.

HERMANN WENDLAND: Bonplandia X: 199.

## BOOKS AND CURRENT LITERATURE

Temperature and Crops.—It is certainly a step in advance when meteorologists and climatologists can turn bone-dry weather data into terms of practical value to the farmer and agriculturist. As long as they are ignorant of the physiological processes going on in plants, just so long will the data they collect be useless to the practical man. At the present time, there are a few meterologists who have taken work in plant physiology and ecology or have the broader view and are able to interpret the weather records, but even these must discover some other means by which their data can be made to mean something.

D. A. Seeley in his article of 1917 on the Relation between Temperature and Crops[1] has shown that what we need more than mean annual, monthly and daily temperatures, is a method of evaluating air temperature in terms of its efficiency to meet the plant's thermal requirements. The temperature of the plant itself should be given more consideration. Curves expressing plant growth rates and plant temperatures show parallellisms more decided than other temperatures observed, including maximum and mean temperatures and soil temperatures. A test of the number of heat units required to cause a cherry tree to blossom in the greenhouse as compared with the outdoors shows remarkably close results when plant temperatures are considered, but when air temperatures alone are considered there is a wide variation.

Mr. Seeley's latest article on The Length of the Growing Season in Michigan[2] shows how the period between the last spring frost and the first autumn frost can be the limiting factor in crop production for certain sections of Michigan.

The records of frosts during the past thirty years or more for many localities in the state have been studied and mathematical calculations made to determine the risk from frost damage on certain dates. Tables are given showing the dates in spring and autumn when there is an even chance that further frosts will occur. The dates are also given when the risks are 33⅓%, 20%, 10% and 5%. A third table gives the frostless season, and with this as a guide and his knowledge of the number of days it takes to mature a particular crop, the farmer may determine the chance of success.

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[1] Seeley, D. A. Relation between temperature and crops. Monthly Weather Review **45**: 354–359. 1917.

[2] Seeley, D. A. The length of the growing season in Michigan. Mich. Acad. Sci. Rept. 20. 1918.

Mention is also made of the influence of the Great Lakes. Along the shore of Lake Superior, frosts occur no later in spring than in most portions of the Lower Peninsula and autumn frosts are delayed by the great mass of water that has been heated during the summer season and has been slow in cooling. Consequently the length of the growing season along Lake Superior is about the same as it is in the central counties of the Lower Peninsula. Along the shores of Lake Michigan the autumn frosts do not occur until about October 20, while 50 to 60 miles inland they come a month earlier. Elevation shortens the growing season. The highlands of the Upper Peninsula and the northern counties of the Lower Peninsula have a later spring frost and earlier autumn frost than the lake counties on the southern tier of counties in the Upper Peninsula.—R. P. HIBBARD.

THE EMBRYOLOGY OF PINUS.—Buchholz[3] has studied the development of the suspensor and early embryo in cones of *Pinus banksiana*, *P. laricio*, *P. sylvestris* and *P. echinata*, collected weekly during the summer months, and his results change materially the general conception of the embryology of the genus. The primitive character of polyembryony due to the cleavage of one egg (as contrasted with polyembryony due to the occurrence of several archegonia in one ovule) which is retained by several genera of Gymnosperms, is much more extensive in *Pinus* than has been indicated in published descriptions. A fertilized egg in the species enumerated above usually produces eight embryos, of which four are the primary embryos commonly figured in texts, arising from the lowest tier of cells of the proembryo, and four are developed from the rosette cells just above the suspensor layer, which thus are shown to be really embryo initials. Rosette embryos are somewhat delayed in development and they probably never contribute the persistent embryo of the seed. Both primary and rosette embryos develop by the division of a fern type of apical cell which is evident in primary embryos up to the 500–700 cell stage and in the rosette embryos as far as they grow. A reduction in the number of cotyledons in *Pinus banksiana* due to the fusion of two primordia is interpreted as suggesting the origin of dicotyledony from polycotyledony. The paper includes a description of the writer's technique for handling pine ovules and is illustrated with five plates and three text figures.—J. G. Brown.

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[3] Buchholz, John Theodore. Suspensor and early embryo of Pinus. Bot. Gaz **66**: 185–222. pls. 6–10. 1918.

# NOTES AND COMMENT

The advance sheets of the Atlas of American Agriculture are now appearing rapidly under the supervision of Dr. O. E. Baker. Particular interest attaches to the first section of the climatic part of the Atlas on Frost and the Growing Season. Maps of the United States, on a scale of 130 miles to the inch, are given to show the average dates of the last and first killing frost, and the average length of the frostless season. Smaller maps show departures from the normal length of the frostless season and the percentage of probability of such departures. Useful as the Atlas promises to be, there will always be a small but important group of workers who will need the data on which the maps are based even more than they need the maps themselves.

The Macmillan Company have recently published a Manual of Vegetable Garden Insects, by C. R. Crosby and M. D. Leonard. The life-histories and methods of control of injurious insects are grouped according to the plants which they attack. The book covers the United States and Canada and is designed to meet the needs of the practical grower of garden crops.

The equipment and work of the Swedish Forest Research Institute, near Stockholm, have been described in one of the series of contributions published by the Institute. It was established in 1907, maintains a staff of six men and is admirably equipped for all lines of forest investigation.

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